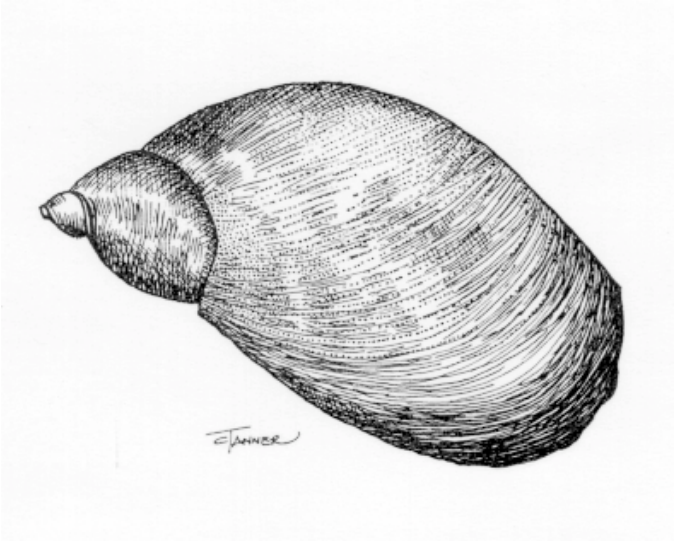
Draft Environmental Assessment: Establishment of a New Wild Population of Kanab Ambersnail in Grand Canyon



Prepared by
the Arizona Game and Fish Department
for
the National Park Service
Grand Canyon National Park

(29 June 1998)

Draft Environmental Assessment: Establishment of a New Population of Kanab Ambersnail in Grand Canyon

LEAD FEDERAL AGENCY:

Department of the Interior
National Park Service
Grand Canyon National Park

LEAD STATE AGENCY:

Arizona Game & Fish Dept.

RESPONSIBLE OFFICIAL:

Park Superintendent
National Park Service
Grand Canyon National Park

COOPERATING FEDERAL AGENCIES:

Department of the Interior
U.S. Fish & Wildlife Service
AZ Ecological Services Office

Department of the Interior
U.S. Bureau of Reclamation
Upper Colorado Region Office

Department of the Interior
Grand Canyon Monitoring and Research Center

Department of the Interior
Central Utah Project Completion Act Office

CONTACTS:

Arizona Game and Fish Dept.
Nongame Branch
2221 W. Greenway Rd. WMNG
Phoenix, AZ 85023
(602) 789-3516

National Park Service
Science Center
P.O. Box 129
Grand Canyon N.P., AZ 86023
(520) 638-7756

U.S. Fish & Wildlife Service
AZ Ecological Services Office
2321 W. Royal Palm Rd.
Suite 103
Phoenix, AZ 85021
(602) 640-2720

U.S. Bureau of Reclamation
Upper Colorado Region Office
UC-320, 125 S. State St.
Room 6107
Salt Lake City, UT 84138-1102
(801) 524-3734

Grand Canyon Monitoring and Research Center
2255 N. Gemini Dr., Room 341
Flagstaff, AZ 86001-1637
(520) 556-7092

Central Utah Project Completion Act Office
302 East 1860 South
Provo, UT 84606-7317
(801) 379-1254

ABSTRACT

The 1996 and 1997 U.S. Fish and Wildlife Service Biological Opinions on the operation of Glen Canyon Dam stipulate the need to establish or discover a second population of the endangered Kanab ambersnail (KAS; Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948) in Arizona before additional Beach/Habitat-Building Flows (BHBF) can occur. BHBFs are controlled floods from Glen Canyon Dam designed to redistribute sediments from the channel bottom to the river banks. Interagency ecological studies and monitoring of the KAS population at Vaseys Paradise, Grand Canyon were conducted between 1994 and 1997. These studies have documented flood impacts to the KAS population and its habitat during the first BHBF in 1996, and subsequent high flows in 1997. Beginning in 1996, the Arizona Game and Fish Department (AGFD) surveyed and evaluated 74 springs, seeps, and wetlands in Grand Canyon and northern Arizona for suitable KAS habitat; no additional KAS populations were found. Eleven sites in Grand Canyon National Park were identified as optimum or more desirable in biological and environmental conditions for establishing new KAS populations. Grand Canyon National Park and AGFD are jointly submitting this draft environmental assessment in the process of establishing new KAS populations. As the preferred alternative, we recommend introducing Vaseys Paradise KASs to three sites simultaneously, to increase the probability of establishment success. Each site should have a minimum population of 100 pre-reproductive KASs (<5 mm in size) in residence prior to overwintering (by the end of October 1998). Supplemental stocking of KASs in 1999 will be required to augment population size and provide genetic variability. Two scenarios for stocking new establishment sites are presented. The preferred alternative lists the following three sites for KAS establishment: "KeyHole Springs" (just downstream of Saddle Canyon on river right), Upper Elves Chasm, and Lower Deer Creek Spring. Other site sets are ranked in order of preference. No adverse effects to natural, cultural, socio-economic resources, visitor use, or listed/special status species is anticipated with the establishment of additional KAS populations. Tribal and visitor access to these sites will not be restricted. The establishment of an additional wild KAS population will satisfy Biological Opinion requirements and alleviate Glen Canyon Dam operational constraints concerning KASs for future BHBFs. In addition, the establishment of new populations will help to meet Recovery Plan downlisting objectives for KASs.

TABLE OF CONTENTS

TABLES

FIGURES

APPENDIXES

ACKNOWLEDGEMENTS

We thank the following individuals and agencies who have helped with the preparation of this Environmental Assessment by providing data, assistance in the field, project funding, or suggestions for improving this document:

Vanessa Dickinson, Terry Johnson, Nancy Olson, and Richard Winstead--Arizona Game and Fish Department

Jan Balsom, Norm Henderson, Elaine Leslie, John Ray, R.V. Ward, and Bob Winfree--National Park Service

Ralph Swanson--Central Utah Project Completion Act Office

Christine Karas, Tony Morton, and Tom Scoville--U.S. Bureau of Reclamation

Debra Bills--U.S. Fish and Wildlife Service

Barry Gold and Larry Stevens--Grand Canyon Monitoring and Research Center

Vicky Meretsky and Eric North--Indiana University

Paul Keim and Clay Nelson--Northern Arizona University

Jim Hoffman (snail taxonomist)

The numerous volunteers and boatmen that assisted in field surveys and data collection.

The Peregrine Fund for providing the document format used previously in the 1995 California Condor Release Environmental Assessment.

Cover illustration by Cindy Tanner, and Figure 1 by Richard Winstead.

Draft Environmental Assessment: Establishment of a New Population of Kanab Ambersnail in Grand Canyon

CHAPTER 1: PURPOSE AND NEED FOR ACTION

A. THE PROPOSED ACTION

In the Biological Opinion for the 1996 experimental Beach/Habitat-Building Flow (BHBF), the U.S. Fish and Wildlife Service (USFWS) set forth Reasonable and Prudent Measures (RPM) related to minimizing incidental take of Kanab ambersnail (KAS; Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948). Specifically, the USFWS established the following Terms and Conditions associated with the RPM, stating:

> "Before another habitat-building flow, Reclamation (U.S. Bureau of Reclamation; USBR) will enter into informal consultation with the Service (USFWS) to evaluate test flow studies, the establishment or discovery of a second population of Kanab ambersnail in Arizona, and reinitiate formal consultation with the Service if incidental take will exceed the 10 percent as established in the 1995 biological opinion."

In layman's terms, "incidental take" can be defined as the loss or death of individuals (in this case, KASs) as a result of man-made disturbances or activities in the affected environment. Based on 1997 data for Vaseys Paradise (IKAMT 1998) a 45,000 cfs (1275 m^3/s) BHBF would currently exceed the 10% incidental take limit for KASs, and thus require USBR to reinitiated formal consultation with USFWS.

The Arizona Game and Fish Department (AGFD) entered into cooperative agreements with the Department of Interior, Central Utah Project Completion Act (CUPCA) Office, the Bureau of Reclamation Upper Colorado Region (USBR), and the Fish and Wildlife Service to conduct habitat evaluations for establishment of at least one new wild population of KAS in Arizona, and to establish a zoological refugium population using AGFD's 12-step reintroduction process (AGFD 1987). This 12-step process was also used for reintroduction of California condors and black-footed ferrets in Arizona. AGFD's 12-step process involves environmental assessments, National Environmental Protection Act compliance, and review by the Arizona Game and Fish Commission, federal agencies, expert biologists, and the public. USBR has committed to provide logistical support for AGFD to establish wild KAS populations and mitigation activities to satisfy Biological Opinion requirements (USBR 1997).

To increase the probability of establishing one viable, self-sustaining, wild population of KAS and thus satisfy terms and conditions of existing biological opinions, AGFD plans to relocate KASs from Vaseys Paradise (VP) to more than one site in the Grand Canyon region. The first proposed translocation is to a maximum of three other sites in Grand Canyon in August 1998, during the reproductive period for KAS. Supplementation of the transplants with additional individuals on 2-3 successive occasions will be necessary. The number of additional KASs to be transferred will depend on the outcome of the first effort. If a founder population appears to establish, supplementation will be with 10 individuals to help ensure the genetic diversity of the VP population is contained in the new population. If it appears the first effort was unsuccessful, larger numbers of KASs, equal to or greater than the number originally transferred, will need to be translocated.

Determination of success will be accomplished during monitoring at the release sites. To maintain consistency in data collection, we will be using the same methods previously used for monitoring the KAS population and habitat of VP. These methods require topographical mapping of vegetation at KAS establishment sites to estimate baseline habitat area, seasonal change in habitat area, and future population estimates.

B. BACKGROUND

Status. In 1992, KAS was federally listed as endangered by the U.S. Fish and Wildlife Service (USFWS 1992). AGFD also recognizes KAS in its draft 1996 *Wildlife of Special Concern in Arizona* (AGFD in prep). Specific threats to KAS involve loss and/or adverse modification to wetland habitat which is scarce in the southwestern United States (USFWS 1995).

Current Distribution. Only two populations of the KAS are known to currently exist in the American Southwest; a third is presumed to have been extirpated in the last decade. One of the extant populations is found in southeastern Utah, on a privately-owned wet meadow dominated by cattails and sedges. The other population of this rare landsnail was discovered in 1991, at Vaseys Paradise (VP) in Grand Canyon National Park (Blinn et al. 1992; Spamer and Bogan 1993). Located 46.8 miles (75.3 km) downstream of Glen Canyon Dam, this site has a large, perennial spring with abundant poison ivy, crimson monkeyflower, and watercress.

Both populations are geographically isolated (92.9 km distant), and believed to be relict from the Late Pleistocene glaciation, when wetland habitat was more abundant (Spamer 1993; Spamer and Bogan 1993; Stevens et al. 1997b). Although the fossil record for *Oxyloma* is scarce, fossil shells have been found in the Grand Gulch area of southeastern Utah (Kerns 1993) and San Pedro Valley of Arizona (Bequaert and Miller 1973). Desertification of the American Southwest over the last 10,000 years has reduced the number and size of available habitats that could sustain KAS populations. The Grand Canyon region is believed to be the most recent historical range of KAS.

Habitat Requirements. Kanab ambersnails, like other succineid snails, are restricted to perennially wet soil surfaces and decaying plant litter of springs and seep-fed marshes near sandstone or

limestone cliffs (USFWS 1995). A limiting factor in their distribution may be the presence of cattails, monkeyflower, or watercress, which are identified as the primary vegetation for KAS habitat (Stevens et al. 1997a). They are most abundant under fallen cattail stalks, decadent monkeyflower litter, or young watercress (USFWS 1995).

Biology. KASs have an approximately annual lifecycle, and reportedly live 12-15 months (Clarke 1991). They emerge from winter hibernation in early spring with the onset of warm weather, and begin reproducing throughout the late spring and summer months. Peak reproduction typically occurs in the late summer (July-August), when densities of mature KASs are highest. A seasonal decline of KASs occurs in early fall with gradual die-offs of mature individuals, while young KASs go into winter dormancy (Stevens et al. 1997a). KASs are hermaphroditic, possessing both male and female sex organs (Pilsbry 1948). Young snails develop from gelatinous egg masses attached to wet plant litter, leaves, or stems. Fully mature KASs can have shell lengths up to 20 mm.

Threats to KAS Existence. The Utah population (Three Lakes; 3L) is threatened by habitat loss and possible extirpation by planned commercial development (USFWS 1995). The VP population is threatened by habitat loss and incidental take from high flow water releases from Glen Canyon Dam (USFWS 1995). This population experienced habitat loss and incidental take during an experimental 45,000 cfs (1275 m^3/s) stage BHBF in March 1996 (Stevens et al. 1997a, 1997b). BHBFs are controlled floods from Glen Canyon Dam designed to redistribute sediments from the channel bottom to the river banks. Natural disturbances to VP may also threaten the KAS population. The talus slope upon which KAS reside at VP was created in the past by an unknown number of debris flows from an ephemeral wash that exits above the VP spring orifices, and future flows could negatively impact the VP KAS population.

Interagency KAS investigators have identified two potential biological threats (both naturally occurring at VP) that may affect KAS. Deer mice (*Peromyscus* spp.) are suspected to be KASs predators (Stevens et al. 1997b). The parasitic trematode (flatworm) in the genus *Leucochloridium* may be another biological threat to individual KASs. Neither of these biological threats are detrimental to VP KAS at the population level, based on information gathered to date. The deer mouse population at VP is relatively small, and there are numerous other invertebrate prey species available to the mice. The trematode parasite is naturally occurring in succineid snails, it is present in both Utah and Arizona populations of KAS (pers. comm. V. Meretsky). Based on interagency studies (1995-1997), *Leucochloridium* is estimated to be present in <10% of VP KAS (Stevens et al. 1997a, 1997b; IKAMT 1998).

Ecological Studies. The USFWS 1994 Biological Opinion on the operation of Glen Canyon Dam required that the VP KAS population and habitat be quantified. The 1996 Biological Opinion specifically addressed the incidental take of VP KAS and habitat loss from the March 1996 experimental BHBF. An interagency team of researchers began ecological studies on KAS at VP in 1994 and continued monitoring through 1997. Representatives of the following agencies/institutions participated in Kanab Ambersnail Working Group (KAWG) activities: AGFD,

Grand Canyon Monitoring and Research Center (GCMRC), National Park Service (NPS), Northern Arizona University (NAU), USBR, and USFWS. Beginning in 1998, KAS monitoring at VP was contracted out to individuals/ organizations through a competitive bid-process established by GCMRC.

C. PURPOSE OF THE PROPOSED ACTION

The 1996 and 1997 USFWS Biological Opinions on the operation of Glen Canyon Dam, concerning BHBFs, identified the need to establish or discover a second wild population of KAS in Arizona, before additional BHBFs could occur. At it's January 1998 meeting, the Adaptive Management Work Group (AMWG) adopted a set of hydrologic criteria that would trigger a BHBF during the spring/summer of 1998 and between January and July in future years. The AMWG also recognized the need to develop biological resource criteria that would be applied, in addition to the hydrologic criteria, and would include compliance with the 1996 Biological Opinion concerning KASs and proposed BHBFs. NPS and AGFD are working together to complete environmental compliance documentation for the establishment of a wild KAS population in Grand Canyon.

The Kanab Ambersnail Recovery Plan (USFWS 1995) provides an outline of KAS recovery objectives. Habitat surveys for KAS were proposed in Task 3.2 of the recovery plan under:

> Identify and survey potential habitat. Potential habitat in spring and seep-fed wetlands near the current range of the Kanab ambersnail will be surveyed for suitable habitat. It is possible that additional Kanab ambersnail populations exist and may be found. Unoccupied potential habitat may have harbored populations of the species in the past and should be considered as reintroduction sites, if necessary. Additional discovered or introduced populations of the Kanab ambersnail will increase its abundance and could contribute to maintaining the species overall viability in the event of a catastrophic loss of one or more of the existing populations.

The KAS Recovery Plan documents the need to establish or discover ten additional KAS populations before their endangered status can be downlisted.

With interagency support, AGFD has conducted exhaustive surveys of 74 springs, seeps, and wetland areas of the Grand Canyon region and northern Arizona between 1996 and 1997. No additional KAS populations were found. Evaluation of potential KAS habitat is documented in AGFD Nongame Technical Reports 122 and 125 (Sorensen and Kubly 1997, 1998). Eleven sites in Grand Canyon National Park were identified as having optimum or more desirable habitat for establishing KAS wild populations (Sorensen and Kubly 1997, 1998). Four additional sites in Grand Canyon, with acceptable habitat, are also included as proposed sites based on high environmental category ratings. Based on preliminary data from single visits, three other sites outside Grand Canyon National Park (two on the Hualapai Reservation and one on the Apache-Sitgreaves National

Forest) were identified as more desirable habitat for KAS. More information on these sites is required before they can be considered as KAS establishment areas.

The attempt to establish multiple KASs populations decreases the likelihood that a catastrophic event would eliminate all the populations and increases the likelihood that each allele will be preserved in a least one population (Leberg 1990). To address these genetic concerns and to increase the probability of success, NPS/AGFD proposes to simultaneously establish three new KASs populations, each having approximately 100 KASs in residence before the end of October (the time most KASs go into winter hibernation). The establishment of a least one wild population of KASs will satisfy the 1996 and 1997 USFWS Biological Opinion requirements concerning BHBFs and KASs.

CHAPTER 2: ALTERNATIVES

A. EVALUATION OF SUITABLE HABITAT

Potential KAS establishment sites were evaluated using a single-species correlation model after extensive field investigations (Sorensen and Kubly 1997; Table 1). Establishment sites were rated on a scale of five levels: (1) optimum; (2) more desirable; (3) acceptable; (4) less desirable; and (5) unsuitable.

Table 1. KAS suitable habitat correlation model (Sorensen and Kubly 1997).

	Optimum	More Desirable	Acceptable	Less Desirable	Unsuitable
Primary Vegetation	More than one type	One type	One type	None (only secondary)	None
Water Source	Perennial spring	Perennial spring or stream	Perennial spring or stream	Perennial spring or stream	Intermittent or Seasonal
Historical Flooding	Rare	Rare	Rare	Periodical	Severe or Frequent
Natural Disturbance	Low	Low	Moderate (or less)	High (or less)	High (or less)
Recreation Use (entire area)	Moderate (or less)	Moderate (or less)	High (or less)	High (or less)	High (or less)
Jurisdictional Protection	High	Moderate	Low	Low	None

In designing a single-species correlation model for KAS we used attributes from VP and 3L sites as the baseline requirements for optimal habitat. With suggestions from KAWG members, we defined unsuitable conditions for KAS establishment. All survey sites would then fall within this range of optimum to unsuitable attributes (Table 2). None of the variables used were weighted--a single unfavorable condition would prevent a site with many high qualities from receiving a higher ranking. This approach was highly conservative, but should increase our chances of successful KAS establishment.

Optimum KAS habitat qualities include: more than one type of primary vegetation present, perennial spring source from a limestone or sandstone geologic strata, rare historic flooding events, low natural and recreational disturbance (specifically to ambersnail habitat, not just the site), and a conservation-based jurisdiction (as opposed to multiple-use land management). Unsuitable KAS habitat was defined as: lack of primary or secondary vegetation; intermittent or seasonal water source; frequent or catastrophic natural disturbance; or severe impacts to habitat by recreation, livestock, agriculture, wildfire, industrial use, or commercial development.

Reasonable access is necessary for KAS establishment and monitoring; however, an area that is difficult to reach can provide added security from recreational impacts and other disturbances. An invertebrate community of high species richness and diversity would indicate suitable environmental conditions for many species of arachnids, insects, and mollusks. There is a lack of information concerning KAS tolerance limits for water quality conditions, as well as detailed physical/chemical analysis of all springs and seeps in Grand Canyon. For these reasons, water quality was not evaluated as a prime category for suitable habitat. Optimum criteria for historical flooding of potential habitat was considered “rare” not “absent.” Both VP and 3L have experienced severe historic flooding in the past, but their KAS populations still persist. Not all of the habitat at these sites, and at proposed establishment sites, would be affected by an occasional flash flood.

Potential KAS establishment sites require jurisdictional or land management authority that provides for species and habitat conservation. Grand Canyon National Park provides the best protection for sensitive wetland habitats from multiple-use practices (i.e., livestock grazing, commercial development, mining, unrestricted recreation access). Management stipulations for most federal lands require the protection of endangered species. State and tribal lands have various land-use mandates, offering less protection to species of concern and sensitive habitats. Jurisdictional protection of KASs and their habitat on state and tribal lands would require case-by-case evaluation. Private landowners may not be willing to protect wetlands or endangered species on their property. For this reason, private land is the least preferable choice for KAS establishment sites.

Table 2. Evaluation of KAS establishment.							
Proposed Sites	Primary Vegetation	Water Source	Historical Flooding	Natural Disturbance	Recreation Use	Jurisdictional Protection	Habitat Ranking
“KeyHole Spring”	O	O	O	O	O	O	O
Thunder River	O	O	O	O	O	O	O
Roaring Springs	O	O	O	O	O	O	O
Lower Deer Spr	O	O	O	MD	O	O	MD
Upper Deer Spr	MD	O	O	O	MD	O	MD
Lower Ribbon Falls	O	O	O	O	MD	O	MD
147.8 mi RR Seep	MD	O	O	O	O	O	MD
Showerbath Spr	MD	O	O	O	O	O	MD
Saddle Canyon	MD	MD	MD	MD	MD	O	MD
Santa Maria Spr	MD	O	O	O	MD	O	MD
Dripping Spring	MD	O	O	O	MD	O	MD
Upper Elves Chasm	MD	O	O	A	O	O	A
Nankoweap Canyon Grape Spring	A	MD	A	O	O	O	A
Kanab Creek Seep	O	O	O	A	O	O	A
Nankoweap Twin Spring	MD	O	A	MD	O	O	A
Suitability Codes: O=Optimum, MD=More Desirable, A=Acceptable							

GRAND CANYON NATIONAL PARK

VP	VASEYS PARADISE	6	DRIPPING SPRING
1	"KEYHOLE SPRING"	7	THUNDER RIVER
2	SADDLE CANYON	8	UPPER DEER CREEK SPRING
3	ROARING SPRINGS	9	LOWER DEER CREEK SPRING
4	LOWER RIBBON FALLS	10	SHOWERBATH SPRING
5	SANTA MARIA SPRING	11	147.8 MI RR SEEP

Detailed site summaries for optimum, more desirable, and selected acceptable sites are documented in Sorensen and Kubly (1997, 1998) and provided in Appendix A. Eleven sites with optimum or more desirable habitat for KAS establishment in Grand Canyon National Park are displayed in Fig. 1.

B. ALTERNATIVE SITES CONSIDERED

The 15 potential establishment sites were divided into 5 sets, from most to least preferred, and these sets are are listed in order of preference based on biological and environmental conditions and perceived management concerns. River miles are expressed as miles downstream of Lee's Ferry (Coconino County, Arizona), and located on either river right (RR) or left (RL).

Specific release areas (patches of primary vegetation away from common trails and campsites) at each site have been identified and UTM geo-referenced. Release areas at all proposed KAS establishment sites are above the 45,000 cfs (1275 m^2/s) stage, and will not be affected by BHBFs of that magnitude or less. To alleviate accidental loss of KASs these release areas could be posted for additional protection from human intrusion (such as "Reveg Area--Keep Out" signs). KAS dispersal outside of release areas could be covered under incidental take limits, thus preventing any access restrictions elsewhere within the sites. USFWS consultation may be required if there are management changes to the site.

Site Set 1. Preferred--sites rated as optimum to acceptable habitat, and low management concerns:

1) "KeyHole Spring" (47.1 mile RR). UTM coordinates: N4024308, E420484.
This site has no known recreation use, and low vulnerability to natural disturbance. The proposed release area has a limited amount of primary vegetation and could only support a small KAS population. This site is located along the river corridor and accessible by existing game trails. This site isolated from other wetland habitat along the river corridor and nearby plateau.

2) Lower Deer Spring (136.1 mile RR). UTM coordinates: N4027916, E364729.

This site has no known recreation use, and moderate vulnerability to natural disturbance (mostly to the floodplain marsh at the lower elevations). The trail leading back into Deer Creek Canyon passes above the spring (5-m below at the base of an overhanging cliff). Dense poison ivy throughout the site keeps visitors out of the habitat. The proposed release area along the upper slope has extensive patches of primary vegetation (estimated at >60 m^2), and could support a large KAS population. This site is located along the river corridor and accessible from the nearby trail (technical climbing gear and Tyvek suits recommended).

3) Upper Elves Chasm (116.6 mile RL). UTM coordinates: N4005750, E369300.
Low recreation use above the sawgrass patch (requires climbing in several areas)--most visitors stay in the lower drainage near the river corridor. Extensive areas of primary vegetation could support a large KAS population. Potential release areas are located along canyon slopes and hanging gardens, away from visitor trails. Habitat along the lower slopes are vulnerable to natural disturbances (flash floods down Royal Arch Creek). This site is located along the river corridor, but requires some non-technical climbing to access.

Site Set 2. Sites rated as more desirable habitat, and low-moderate management concerns:

4) Lower Ribbon Falls (N. Kaibab Trail). UTM coordinates: N4001950, E405250.
This site has moderate recreation use, and low vulnerability to natural disturbance. Two large patches of primary vegetation (currently posted with "Reveg Area--Keep Out" signs) could support a large KAS population. This site is accessed by a 7.8-mile (12.6 km) hike from the North Rim (North Kaibab Trail). Area identified as culturally sensitive.
5) 147.8 mile RR Seep. UTM coordinates: N4023876, E350129.
This site has no known recreation use, and low vulnerability to natural disturbance. There are small patches of primary vegetation which could only support a small KAS population. This site is located along the river corridor and accessible by existing game trails. There is two genera of landsnails at this site.

6) Showerbath Spring (12.9 km up Kanab Crk). UTM coordinates: N4035700, E353000.
This site has low recreation use, and low vulnerability to natural disturbance. This site could support a moderate-size KAS population. A large patch of primary vegetation is located on the upper slope of an overhang, 3-m above the creek--the overhang is inaccessible without technical climbing gear. This site is located approximately 8 miles (12.9 km) from the river corridor, and accessible by a primitive trail. Overnight backpacking and technical climbing gear would be required.

7) Saddle Canyon (47.0 mile RR). UTM coordinates: N4024050, E418850.
This site has high recreation use, but most visitors stay out of potential habitat (trampled veg at lower stream crossings). Abundant amount of primary vegetation could support a large KAS population. Potential release area was identified away from visitor trails, but still

vulnerable to moderate natural disturbance. This site is accessed by a 3/4 mile (1.2 km) hike from the river corridor.

Site Set 3. Sites rated as optimum or more desirable habitat, but with high management concerns:

8) Thunder River (upper Tapeats Crk). UTM coordinates: N4028650, E369350.
The entire site has moderate recreation use (limited to 35 campers/night at the Tapeats primitive campsite), but most visitors stay out of potential habitat (minor trampled veg at lower stream crossing). This area is one of the more popular backcountry recreation sites in the Canyon and NPS has significant management concerns with KAS introduction in this high use area. Numerous areas of primary vegetation could support a large KAS population. Potential release areas were identified away from visitor trails, and were less likely to be affected by natural disturbances. This site is accessed by a 2-mile (3.2 km) hike from the river corridor. There are eight genera of landsnails existing at this site.

9) Roaring Springs (N. Kaibab Trail). UTM coordinates: N4006077, E406809.
NPS has management concerns on water use restrictions--springs are the main water source for North and South Rim resorts. This site has high recreation use (>100 visitors/day), but most visitors stay out of potential habitat (some trampled veg along the creek and lower drainages). Numerous areas of primary vegetation would support a large KAS population. This site is accessed by a 4.5-mile (7.2 km) hike from the North Rim (North Kaibab Trail). There are at least eight genera of landsnails existing at this site.

10) Upper Deer Spring (136.1 mile RR). UTM coordinates: N4029168, E365341.
Moderate recreation use at the base of the spring, but most visitors stay out of potential habitat along the lower drainage (due to dense tree/shrub canopy). Numerous areas of primary vegetation could support a moderate-sized KAS population. Potential release areas were identified away from visitor trails, and were less likely to be affected by natural disturbances. This site is accessed by a 1-mile (1.6 km) hike from the river corridor. Area identified as culturally sensitive.

11) Santa Maria Spring (S. Hermit Trail). UTM coordinates: N3991100, E390010.
NPS has management concerns on water use restrictions--spring is regularly used by hikers. This site has moderate recreation use, but most visitors stay out of potential habitat (some trampled veg along the trail). A large patch of primary vegetation on the upper slope could support a large KAS population. This site is accessed by a 1.3-mile (2.1 km) hike from the South Rim (South Hermit Trail).

12) Dripping Spring (S. Hermit Trail). UTM coordinates: N3991450, E388150.
NPS has management concerns on water use restrictions--spring is regularly used by hikers. This site has moderate recreation use, but most visitors stay out of potential habitat (some

trampled veg near water catchment basin). Limited amount of primary vegetation could support a small KAS population. This site is accessed by a 2.5-mile (4.0 km) hike from the South Rim (South Hermit Trail).

Site Set 4. Sites with acceptable biological and environmental conditions, but may require site modifications:

13) Nankoweap "Canyon Grape Spring" (52.1 mile RR). UTM coordinates: N4017075, E421500. No known recreation use, although the base of the spring may be affected by natural disturbance (flash floods down Nankoweap Creek). Most visitors stay out of potential habitat along the upper slopes due to dense canyon grape and sawgrass. Limited amount of primary vegetation could only support a small KAS population. This site is accessed by a 2-mile (3.2 km) hike from the river corridor.

14) Kanab Creek Seep (143.4 mile RR). UTM coordinates: N4030700, E354400.
No known recreation use, although the base of the spring may be affected by natural disturbance (flash floods down Kanab Creek). Most visitors bypass this seep on the route to "Whispering Falls" or the river corridor. Limited amount of primary vegetation could only support a small KAS population. This site is accessed by a 1.5-mile (2.4 km) hike from the river corridor.

15) Nankoweap "Twin Springs" (6.4 km up Nankoweap Crk). UTM coordinates: N4015350, E420150. Low recreation use, although dense sawgrass keeps most visitors out of the habitat. The base of the spring may be affected by natural disturbance (flash floods down Nankoweap Creek). Limited amount of primary vegetation could only support a small KAS population. This site is accessed by a 4-mile (6.4 km) hike from the river corridor.

Sites 13-15 may require planting additional host vegetation, diversion or retention of water, and/or construction of flood control barriers to be more suitable for KAS populations.

C. TIMING OF THE PROPOSED ACTION

Considerations for timing of proposed translocations of KAS include proposed BHBFs, the period of reproductive activity, availability of different life stages, and winter dormancy. The most opportune times to translocate KASs may well be compromised by BHBFs. Those KASs living in the lower vegetation zone of VP are likely to be inundated by a BHBF, and will probably be swept downstream and perish. KASs living in the habitat below the BHBF's stage discharge elevation should be removed prior to the flood, and can be used for translocations. This is an important consideration in reducing the incidental take for VP KASs and providing a founding stock that would have been lost anyways.

Most KASs at VP secrete a mucoid plug (epiphragm) to close the foot opening in the shell and overwinter on rock surfaces or dry plant material in a dormant state. Transition to the overwintering state typically begins in October. Overwinter mortality can be quite high, in some years >50% of the autumn population. We consider the period of overwintering, November-February to be generally unsuitable for moving KASs unless some factor, such as a BHBF during this period, will cause losses of individuals that could be moved.

Most KASs that successfully overwinter are immatures; individuals that reached adulthood in the previous year typically perish during this period. From March through May, KASs are growing and amassing energy stores to be used in reproduction. There are relatively few adults or individuals <5 mm in length available during much of this period. Movement of pre-reproductive individuals to new sites during spring months would allow for production of progeny in the new site during the normal reproductive period of May-August. Individuals produced at the new site can then grow and enter the period of overwintering at that site. The only drawback to this scenario is that individuals may be moved who harbor the trematode parasite, *Leucochloridium*. The parasite is not expressed (visible) until KASs reach lengths of >13 mm.

From June through September, all size classes of KASs, including eggs, are available for translocation. Movement of reproductive age individuals becomes increasingly less suitable as this period progresses, because these individuals have little chance of surviving the winter at the new site. Any transfer of adult KASs risks the movement of individuals infected with the parasite *Leucochloridium*. Movement of egg masses has been tried on one occasion. Twelve egg masses were transported from VP to NAU in August 1997. Researchers involved in the transport did not isolate the eggs and thus were not absolutely sure of their fate, but the transfer did not appear to be successful (pers. comm. C. Nelson). One KAS investigator observed that the eggs began to darken within an hour of being collected (pers. comm. V. Meretsky). She believes this was an indication of unsuitable conditions, and that successful transfer of egg masses will require a much better understanding of their environmental tolerances coupled with better environmental controls during the transfer. In the same effort, NAU researchers moved 248 immature KAS (<4.5 mm in size). Most of these individuals survived, and as of June 1998 they have produced >900 progeny after three generations. None of the transported immature KASs have shown any evidence of *Leucochloridium* infestation.

D. PROPOSED ALTERNATIVES

Alternative 1 (Preferred). Establish a new population of Kanab ambersnail in Grand Canyon National Park.

NPS/AGFD propose to establish a wild population of KASs in Grand Canyon National Park, by simultaneously relocating KASs from VP to three proposed sites with suitable habitat. Using three sites concurrently will increase the probability of successful establishment of one population. A

long-term refugium population of KASs will also be started at The Phoenix Zoo (TPZ). Wild stock of KASs will be taken from VP to maintain genetic integrity and simplify logistic and monitoring activities. Based on discussions with P. Keim (geneticist at NAU) and a review of scientific literature (see Chapter 3), a genetically-stable population of mollusks would require a minimum of 50-100 reproductive individuals contributing successive progeny. An annual immigration of 1-5 individuals (also reproductively contributing) to this population are required for genetic variability. Specifics on collection and transportation protocol and planned monitoring will be provided in a NPS/AGFD Biological Evaluation to the USFWS.

Early life stage KASs (<5 mm immatures and/or egg masses) will be translocated in August 1998. Any KASs exhibiting visible sporocysts of *Leucochloridium* will not be translocated. Each site should have approximately 100 KASs in residence prior to the end of October. These residents should be acclimated to the new site, and have grown sufficiently (5-10 mm in size) to enable them to survive winter hibernation. With a predicted overwinter mortality of 50%, half this population may survive to contribute reproductively to successive generations. Additional translocations of KASs in 1999 will help augument new site populations and maintain genetic intergrity. AGFD monitoring trips in spring, early summer, and late summer 1999 will ascertain secondary population establishment success and conduct population estimates and habitat mapping.

Establishment of a new population will satisfy the 1996 and 1997 Biological Opinion requirements for Glen Canyon Dam operations concerning KASs. Likewise, establishment of additional KAS populations will progress the KAS Recovery Plan objectives. Ten new populations are required for KASs to be downlisted to threatened status.

Alternative 2. No action (status quo).

This option will not satisfy USFWS Biological Opinion requirements (USFWS 1996, 1997) for the operation of Glen Canyon Dam, and future implementation of BHBFs. In addition, a no action option will not satisfy KAS recovery objectives, and will not benefit the species.

CHAPTER 3: ENVIRONMENTAL CONSEQUENCES

A. NATURAL RESOURCES

1. Affected environment: KAS establishment sites are located in specific wetland habitats in Grand Canyon National Park. KASs are restricted to wetland habitats in proximity to limestone or sandstone cliffs. Specifically, KASs live in moist, vegetated areas that are dominated by cattails,

monkeyflower, and/or watercress. Founding stock of KASs for new establishment sites will be taken from VP.

2. Impacts: Establishment of KASs in wetland habitats will not adversely affect the physical landscape, watershed, local fauna, or vegetative communities if parasite-free stock is used as described in Chapter 4. KAS establishment may indirectly benefit local flora and/or fauna in wetland habitats with additional federal protection covered by ESA compliance. Sites 13-15 may require habitat modification (described in Chapter 2) that would physically benefit the local flora and/or fauna. KASs from VP will be relocated during their peak reproductive period in July-August, causing the least impact to the host population.

B. CULTURAL RESOURCES

1. Affected environment: Based on limited information, cultural resource concerns were identified for two proposed KAS establishment sites (Lower Ribbon Falls and Upper Deer Creek Spring). Both areas are of religious significance to the regional Native American tribes (pers. comm. R. Winfree). Additional input by the regional Native American tribes is requested through the public scoping process associated with this environmental assessment.

2. Impacts: KAS establishments will not adversely affect cultural resources or tribal access to sites in Grand Canyon. Based on historical use, tribal and visitor access to these sites will not be restricted.

C. SOCIO-ECONOMIC RESOURCES

1. Affected environment: localized wetland habitats in Grand Canyon National Park.

2. Impacts: KAS establishments will not adversely affect socio-economic resources in Grand Canyon. Grand Canyon National Park does not allow mining, livestock grazing, timber harvesting, hunting, or commercial development within park boundaries--therefore, these activities will not be affected by Kanab ambersnail establishment.

D. VISITOR USE

1. Affected environment: localized wetland habitats in Grand Canyon National Park.

2. Impacts: KAS establishments will not adversely affect recreation use in proposed establishment sites. Proposed release areas at each site are located outside normal visitor use areas, and often have natural barriers to human intrusion (i.e., presence of poison ivy, dense vegetation, cliffs or overhangs). Visitor access to these sites will not be restricted, unless NPS chooses to designate KAS release areas as protected. NPS is concerned that release of KAS at sites 8-12, areas that receive high recreation use, may significantly restrict visitor use at these sites.

E. LISTED AND SPECIAL STATUS SPECIES

STATUS DEFINITIONS

LE - Listed Endangered. Species identified by the USFWS under the ESA as being in jeopardy of extinction.

LT - Listed Threatened. Species identified by the USFWS under the ESA as being in jeopardy of becoming endangered.

WC - Wildlife of Special Concern in Arizona (WSCA). Species whose occurrence in Arizona is or may be in jeopardy, or with known or perceived threats or population declines, as described by the AGFD's listing of *Wildlife of Special Concern in Arizona* (AGFD in prep.).

S - Sensitive. Species classified as "sensitive" by the Regional Forester when occurring on lands managed by the Department of Agriculture U.S. Forest Service.

SR - Salvage Restricted. Those Arizona native plants not included in the Highly Safeguarded Category, but that have a high potential for theft or vandalism, as described by the Arizona Native Plant Law (1993).

1. Affected species and critical habitat: The AGFD's Heritage Data Management System (HDMS) was queried and current records show that the special status species listed below have been documented as occurring in the following project vicinities (within 5 miles [8.0 km]):

Site 1: “KeyHole Spring”

COMMON NAME	SCIENTIFIC NAME	STATUS
Grand Canyon primrose	*Primula specuicola*	SR
Southwestern willow flycatcher	*Empidonax traillii extimus*	LE,WC

Sites 2 and 10: Lower Deer Spring and Upper Deer Spring

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S

Site 3: Upper Elves Chasm

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Mexican spotted owl	*Strix occidentalis lucida*	LT,WC,S

Site 4: Lower Ribbon Falls

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Humpback chub	*Gila cypha*	LE,WC,S
Kaibab beardtongue	*Penstemon virgatus pseudoputus*	S
Kaibab paintbrush	*Castilleja kaibabensis*	S
Mogollon columbine	*Aquilegia desertorum*	S,SR
Northern goshawk	*Accipiter gentilis*	WC,S
Roaring Springs prickly-poppy	*Argemone arizonica*	S
Western red bat	*Lasiurus blossevillii*	WC,S

Site 5: 147.8 mile RR Seep

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Grand Canyon flaveria	*Flaveria Mcdougallii*	SR
Humpback chub	*Gila cypha*	LE,WC,S

Site 6: Showerbath Spring

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Humpback chub	*Gila cypha*	LE,WC,S

Site 7: Saddle Canyon

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Grand Canyon primrose	*Primula specuicola*	SR
Southwestern willow flycatcher	*Empidonax traillii extimus*	LE,WC

Site 8: Thunder River

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Northern goshawk	*Accipiter gentilis*	WC,S

Site 9: Roaring Springs

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S

Kaibab beardtongue	*Penstemon virgatus pseudoputus*		S
Kaibab paintbrush	*Castilleja kaibabensis*	S	
Mogollon columbine	*Aquilegia desertorum*		S,SR
Northern goshawk	*Accipiter gentilis*		WC,S
Roaring Springs prickly-poppy	*Argemone arizonica*		S

Sites 11 and 12: Santa Maria Spring and Dripping Spring:

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Grand Canyon rose	*Rosa stellata abyssa*	S,SR
Grand Canyon catchfly	*Silene rectiramea*	S
Greater western mastiff bat	*Eumops perotis californicus*	S

Sites 13 and 15: Nankoweap "Canyon Grape" and "Twin Springs":

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Grand Canyon primrose	*Primula specuicola*	SR
Humpback chub	*Gila cypha*	LE,WC,S
Southwestern willow flycatcher	*Empidonax traillii extimus*	LE,WC
Roaring Springs prickly-poppy	*Argemone arizonica*	S

Site 14: Kanab Creek Seep

COMMON NAME	SCIENTIFIC NAME	STATUS
American peregrine falcon	*Falco peregrinus anatum*	LE,WC,S
Grand Canyon flaveria	*Flaveria mcdougallii*	SR
Humpback chub	*Gila cypha*	LE,WC,S

In addition, the project appears to occur within designated Critical Habitat for the humpback chub (*Gila cypha*) (59 Federal Register 13374, March 21, 1994), razorback sucker (*Xyrauchen texanus*) (59 FR 13374, March 21, 1994), and Southwestern willow flycatcher (*Empidonax traillii extimus*) (58 FR 39495, July 23, 1993).

2. Impacts: Establishment of wild KAS populations will not adversely affect any special status species in the vicinity of establishment sites. KASs are terrestrial snails, restricted to wetland areas, and will not impact endangered native fish. No Southwestern willow flycatcher, American peregrine falcon, or Mexican spotted owl nesting sites were discovered at proposed KAS establishment sites. Proposed KAS sites are distant enough that establishment and monitoring activities will not disturb these avian species. KASs will not migrate into the surrounding xeric landscape of Grand Canyon wetlands, and will not affect special status flora listed above. Access to proposed KAS sites will be light (once each season), and will utilize existing game trails and hiking trails. When possible, these activities will be coordinated with other science trips or investigators to lower costs and reduce the time and logistics required.

F. OTHER CONCERNS

This section addresses concerns raised by interagency investigators, resource managers, and KAWG participants on the following topics: competition with other mollusks, infection and dispersal of the KAS parasite, captive-breeding programs, the TPZ refugium, founder population size, and risks of using egg masses for translocation. Citations to related scientific literature, government reports, and recent unpublished data/personal communications are provided to support the following conclusions.

Interspecific competition among mollusk species is not anticipated with establishing wild KAS populations. Of the 15 proposed KAS establishment sites only Thunder River, Roaring Springs, and

147.8 mi RR Seep have more than one species of landsnails. Most proposed sites only harbor populations of *Catinella* (succineid landsnails), *Physa=Physella* (aquatic snails), and/or *Deroceras* (marsh slugs). While KASs and *Catinella* coexist at both VP and 3L, they appear to spatially segregate along steep moisture gradients, and may have distinct niche requirements (pers. comm. L. Stevens). Stevens also contends that an introduced species to a site with multiple assemblages and little niche overlap, may substantially affect niche segregation. While Thunder River and Roaring Springs may fit this description (each having at least eight different genera of landsnails [Spamer and Bogan 1993; Stevens et al. 1997a; Sorensen and Kubly 1997; pers. comm. E. North]), the only close succineid neighbor would be *Catinella*. KAS and *Catinella* are more "amphibious" in habitat selection (close proximity to water), than say the talussnails *Oreohelix* or *Sonorella*, which prefer drier litter/duff and limestone talus. Likewise, succineid snails are pulmonates (air-breathing), and will not displace aquatic snails for habitat. Documented evidence of species displacement in Grand Canyon region mollusks is lacking.

Hoffman (1990) indicates that competition occurs in the sympatric species of *Sonorella grahamensis* and *S. imitator* in the Pinaleno Mountains, southern Arizona. Character displacement may occur between closely related species sharing the same habitat, as documented in studies of *Cepaea* spp. (Fretter and Peake 1978). The degree of relatedness in both of these examples of competition are congeneric (same genus); familial and ordinal levels of mollusks are unlikely to compete (pers. comm. J. Hoffman).

J. Hoffman (pers. comm.) believes that most mollusk genera coexist successfully within the same habitat, even species of the same genus if they are not extremely similar. *Oxyloma* and *Catinella*, both in the family Succineidae, are successfully coexisting at VP and -9 Mile Spring (-9M) Lee's Ferry (i.e., the Niobrara ambersnail, *Oxyloma haydeni haydeni*). The widespread distribution of *Catinella* spp. indicates less stringent habitat requirements than *Oxyloma* spp. AGFD has observed *Catinella* at -9M to be more abundant in rushes, sedges, and various grasses, with less overlap in *O. h. haydeni* habitat of cattails and watercress. More competition would be expected if KAS and *O. h. haydeni* occupied the same site, with a greater overlap of habitat use.

Interagency studies at VP confirm that KAS is an intermediate host for the parasitic trematode, *Leucochloridium cyanocittae* (pers. comm. P. Lewis Jr.; Stevens et al. 1997a). In June 1998, two KASs from the Utah population were observed with parasite sporocysts (pers. comm. V. Meretsky). Trematode parasitism of KASs appears to be regionally dispersed, not a local phenomenon. Furthermore, if this parasite is being distributed by passerine birds throughout Grand Canyon and vicinity, infestation at new establishment sites may be uncontrollable.

Current research has not demonstrated significant effects (either positive or negative) of *Leucochloridium* on KASs life cycle, population dynamics, or reproduction. Stevens and Price (1998) believe infected KASs may have a lower level of fitness and/or reduced reproductive potential. In August 1997, two parasitized KASs (both 15 mm in size) were found to be capable of

laying egg masses (Sorensen and Kubly 1998). One KAS, with two sporocysts, was later dissected. The reproductive tract was reported to be intact, even with the presence of the 12 mm-long sporocysts (pers. comm. J. Hoffman). Parasite infection of the KAS population at VP is low (<10% total population 1995-1997 [Stevens et al. 1997a, 1997b; IKAMT 1998]), and likely has evolved naturally with this population.

Relocated KASs, infected with the parasite are unlikely to contaminate existing mollusk populations at proposed establishment sites. Baer (1971) reports that the genus *Leucochloridium* may parasitize many species of passerine birds (definitive hosts), but always selects *Succinea* spp. (in the same family as *Oxyloma* and *Catinella*) as the molluscan intermediate host. However, KAS investigators have not observed this parasite in other molluscan species at VP or other locations throughout Grand Canyon and vicinity. Likewise, AGFD has not found any scientific literature on other landsnails, aquatic snails, or slugs as being intermediate hosts for the genus *Leucochloridium*. Currently, there is no scientific evidence that the native parasite *L. cyanocittae* is detrimental to KASs at the population level, or to any other landsnails in the Grand Canyon region.

The risk of *Leucochloridium* infecting new KAS populations is present regardless of transport method or founder stock. Certain precautions can be taken to reduce the occurrence of this parasite in new KAS populations. Mature KASs (>13 mm in size) can be examined for visible sporocysts. One method for screening trematode parasites requires moving KASs into a sterile holding facility to raise new progeny. Propagation is a time and effort-intensive process requiring environmentally-controlled enclosures, acquisition and maintenance of host vegetation and mollusks, necessary state and federal permits, and compliance with the draft USFWS captive-breeding policy and American Zoo and Aquarium Association Species Survival Plan (SSP) guidelines.

TPZ is well equipped to handle a large, long-term population of KASs as a refugium. However, a June 1998 memo from their KAS refugium manager (M. Demlong) cautions that a significant change in their role (from refugium to rearing KASs for reintroduction) may force them to withdraw their participation. Demlong cites several reasons that currently prevent TPZ from propagating KASs for reintroduction stock: lack of additional funding and available staff (rearing efforts are 10 times more labor intensive); expensive refugium enclosures have already been built, and were not designed to propagate large numbers of snails; TPZ would need legal clarification of their requirements under the draft USFWS captive-breeding policy; and the September 1998 moratorium on establishing new studbooks or SSPs.

There is no 100% guarantee that new KAS populations will be parasite-free, even using captive-bred stock. Passerine birds that range throughout the Grand Canyon region can infect new KAS populations after establishment. In addition, Baer (1951) reports that the encysted metacercaria (minute, larval stage) of *Leucochloridium* can be directly passed by infected mollusks to the surrounding vegetation. Other KASs grazing on this vegetation may ingest the expelled metacercaria and become infected. Moving egg masses from VP would require moving a small amount of

vegetation to which the egg masses are attached. Metacercaria are too small to identify on vegetation surfaces in the field. Even if a trained technician using a microscope examined the vegetation, the microscope lamp would bake the egg masses rendering them inviable.

The risk of KAS transplant failure is increased by moving the snails from a wild setting to an artificial one, and then back to the wild. Even if captive-breeding facilities are initially sterile environments, there is always a risk of containment failure and possible introduction of foreign pathogens/parasites. For example, in April 1998, a KAWG visit of the NAU facility (housing a 10j-status KAS population) discovered 12 KASs had escaped from their enclosures, and were within a 2 m proximity of another mollusk species held on site. This situation raises concerns of security and the potential of contamination of KAS breeding stock. Using a propagation facility would also increase the logistical support required, and may exceed the time frame for current project funding and staff participation.

Other snails at risk have been successfully reared in captivity with the intent to re-establish wild populations. These include seven species of *Partula*, Pacific islands endemics extirpated by the introduced predaceous snail *Euglandina* (Johnson 1991), and the Chittenango ovate ambersnail (*Novisuccinea chittenangoensis*), a New York endemic threatened by the introduced pest snail *Succinea* sp. B (Breisch 1996). In both cases, reproduction in captivity has increased the number of individuals for release into the wild, but no pest-free establishment sites have been found. These captive breeding populations were not intended to raise parasite-free stock, rather to boost population sizes that were being decimated by predation and displacement in the wild. There is little reason to believe that translocating snails from a wild source to other sites will be any less successful than efforts to create captive populations. This is especially true when suitable sites are close to the KAS source at VP, and are biologically and environmentally similar. Furthermore, it has been shown in numerous species that re-establishment or introduced populations from wild stock, rather than captive stock, have higher fitness and survival potential (pers. comm. M. Demlong).

There are three general genetic factors affecting persistence of small populations. First is founder size (Fitzsimmons et al. 1997). If founder population size is small, founders may carry only a part of the total genetic variability of the source population due to sampling error. Second, loss of genetic heterozygosity can affect the short-term success of introduced populations (Leberg 1990) by possibly reducing population growth, fecundity, and survival rates. An individual is heterozygous for a gene when it has received a different allele from each parent; heterozygosity decreases as individuals become more inbred. Last, allelic diversity affects the ability of a population to adapt to changing environments (Lacey 1987). The population may become vulnerable to new predators, diseases, parasites, climatic conditions, competitors, and changing food supplies.

Viable population size determined from genetic analyses alone should be used only as a rough estimate of the minimum number of individuals desirable within a population (Reed et al. 1988). For vertebrates, founding population sizes of 10 or more individuals can retain most (• 95 percent)

of the heterozygosity in the source population (Leberg 1990), assuming all individuals survive and successfully produce offspring. However, small populations tend to lose genetic variation by genetic drift more rapidly than larger populations (Lacey 1987). Also the longer a population remains small, the more genetic variation it will lose (Leberg 1992). Genetic drift, due to random sampling of genes during transmission from one generation to the next, can be most effectively controlled by keeping breeding populations large. If all adults contribute equally to the succeeding generations, founding population sizes of 50 or more individuals would experience • 1% loss of heterozygosity to the next generation (LaCava and Hughes 1984), the maximum amount acceptable to animal breeders (Reed et al. 1986). Periodic immigration can drastically reduce genetic drift away from characteristics of the source population, and as few as one immigrant per two generations could be beneficial (Lacey 1987). Although KASs have little or no immigration (and gene flow) among isolated populations, sequential capture and release of new founder stock is possible for maintenance of genetic variation.

Stevens et al. (1997a) reports KAS egg masses having a range of 5-25 eggs each, and mean egg mass density/m^2 at VP (two dates in mid-August 1995) was 5.2 to 5.3 (SD=11.9 and 15.0 respectively). A captive-breeding experiment on *Novisuccinea chittenangoensis* (Molloy 1995) had six founder snails that produced 130 F_1 hatchlings from 220 eggs (13 egg masses), but only eight F_1 snails survived to maturity (a 3.6% survivorship). Of those eight F_1 snails, four produced egg masses for the next generation (Molloy 1995). In August 1997, 12 egg masses from VP were relocated to NAU along with 248 young KASs for an experimental population. These egg masses are believed to had 0% survivorship (pers. comm. C. Nelson). Because the viability and successful hatching of transported KAS egg masses is expected to be poor, a large number of egg masses would need to be collected for an establishment effort. Obtaining sufficient numbers of egg masses (total 1000 eggs/site with a 5% survivorship=50 mature KASs) would require more intensive searching (possible impact) of primary vegetation at VP.

KAS egg masses would be difficult to distinguish from *Catinella* or *Deroceras* egg masses. Egg masses found on watercress at VP, in mid-summer, are >90% likely to be KASs (pers. comm. L. Stevens). In addition, there is considerable risk of losing KAS egg masses in transit due to desiccation and maintaining appropriate temperature and humidity levels (tolerances currently unknown). Once placed at new sites KAS egg masses are subject to predation or weather-induced displacement (heavy rains or winds).

CHAPTER 4: LIST OF PERSONS AND AGENCIES CONSULTED

*Dennis Kubly, Terry Johnson, *Mike Mallett, *Jeff Sorensen, and Richard Winstead, Nongame Branch, Arizona Game and Fish Department

Vanessa Dickinson and Nancy Olson, Habitat Branch, Arizona Game and Fish Department

Jan Balsom, *John Ray, *R.V. Ward, and *Robert Winfree, Grand Canyon National Park, National Park Service

*Debra Bills, U.S. Fish and Wildlife Service

*Mike Demlong, The Phoenix Zoo

*Christine Karas, Tony Morton, and *Tom Scoville, Upper Colorado Region Office, U.S. Bureau of Reclamation

*Ralph Swanson, Central Utah Project Completion Act Office

*Barry Gold and *Larry Stevens, Grand Canyon Monitoring and Research Center

*Vicky Meretsky and Eric North, Indiana University

*Paul Keim and Clay Nelson, Northern Arizona University

*Norm Henderson, Glen Canyon National Recreation Area, National Park Service

Jim Hoffman (snail taxonomist)

* Denotes Kanab Ambersnail Working Group (KAWG) participants

CHAPTER 5: PREPARERS AND BIBLIOGRAPHIES

JEFF A. SORENSEN, Wildlife Specialist, Nongame Branch, Arizona Game and Fish Department. Jeff participated in interagency monitoring of the Vaseys Paradise population (March 1996-October 1997), and conducted field habitat surveys/evaluation criteria for establishment sites (June 1996-present). Jeff has a Bachelor of Science degree in biology from Northern Arizona University, and has worked for the Department for over seven years on various fisheries and ecosystem projects. Between 1990-1992, Jeff conducted water quality and primary production studies in the Lee's Ferry reach of Glen Canyon.

DENNIS M. KUBLY, Support Supervisor, Nongame Branch, Arizona Game and Fish Department. Dennis participated in interagency monitoring of the Vaseys Paradise population (September 1994-April 1996), and is the project coordinator for the Department's KAS establishment efforts (June 1996-present). Dennis has a Masters of Arts degree in biology from Mankato State University, and has worked for the Department for over thirteen years on various research and nongame wildlife projects. Dennis conducted invertebrate and limnologic studies of Grand Canyon springs and tributaries in the mid-1970s, and served as the Department's Glen Canyon Environmental Studies Project Statistician (Phase 1) and Program Manager (Phase 2).

W. MICHAEL MALLETT, Wildlife Specialist, Nongame Branch, Arizona Game and Fish Department. Mike began working on Kanab Ambersnail recovery objectives in April 1998 and has conducted habitat surveys for potential establishment sites. Mike has a Bachelor of Science degree in Biology from Arizona State University and a Master of Science degree in Zoology from Oklahoma State University. Mike conducted studies on nutrient dynamics of midwestern stream ecosystems.

LITERATURE CITED

Arizona Game and Fish Department (AGFD). 1987. Procedures for nongame wildlife and endangered species re-establishment projects in Arizona. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix, Arizona.

AGFD. (in prep.). *Wildlife of Special Concern in Arizona*. Nongame and Endangered Wildlife Program, Arizona Game and Fish Department, Phoenix, Arizona.

Baer, J.G. 1951. Ecology of Animal Parasites. University of Illinois Press, Urbana. 224 pp.

Baer, J.G. 1971. Animal Parasites (translated from the French by Kathleen Lyons). World University Library, McGraw-Hill Book Co., New York. 255 pp.

Bequaert, J.C. and W.B. Miller. 1973. The Mollusks of the Arid Southwest; with an Arizona Check List. University of Arizona Press, Tucson.

Bills, D.T., D.M. Kubly, J.A. Sorensen, and L.E. Stevens. (in prep.). Contingency plan for relocating endangered Kanab ambersnails from Vaseys Paradise, Grand Canyon, in the event of an emergency, high discharge flood from Glen Canyon Dam. Draft document to the interagency Kanab Ambersnail Working Group.

Blinn, D.W., L.E. Stevens, and J.P. Shannon. 1992. The effects of Glen Canyon Dam on the aquatic food base in the Colorado River corridor in Grand Canyon, Arizona. U.S. National Park Service report (NPS Cooperative Agreement No. CA-8009-8-0002).

Breisch, A.R. 1996. Status, research and management of the Chittenango ovate amber snail. New York Department of Environmental Control Endangered Species Investigations Performance Report W-166-E.

Clarke, A.H. 1991. Status survey of selected land and freshwater gastropods in Utah. Final Report. Contract no. 14-16-0006-89-021 (revised) (prepared for the U.S. Fish and Wildlife Service), Ecosearch, Inc., Portland, Texas.

Clover, E.U. and L. Jotter. 1944. Floristic studies in the canyon of the Colorado and tributaries. American Midland Naturalist 32: 591-642.

Cole, G. and D.M. Kubly. 1976. Limnologic studies on the Colorado River and its tributaries from Lee's Ferry to Diamond Creek including its course in Grand Canyon National Park.

Colorado River Research Program, Report Series, Grand Canyon National Park, Technical Report 8.

Cooley, M.E., B.N. Aldridge, and R.C. Euler. 1977. Effects of the catastrophic flood of December 1966, North Rim area, eastern Grand Canyon, Arizona. U.S. Geological Survey Professional Paper 980. Washington D.C.

Fitzsimmons, N.N., S.W. Buskirk, and M.H. Smith. 1997. Genetic changes in reintroduced Rocky Mountain bighorn sheep populations. Journal of Wildlife Management 61:863-872.

Foust, R.D. Jr. and S. Hoppe. 1985. Seasonal trends in the chemical composition of Grand Canyon waters. National Park Service report. Northern Arizona University, Flagstaff. 81 pp.

Fretter, V. and J. Peake. 1978. Pulmonates: Vol 2A; systematics, evolution, and ecology. Academic Press, London.

Hoffman, J.E. 1990. Status survey of seven land snails in the Mineral Hills and the Pinaleno Mountains, Arizona. Contract report 20181-88-00973 to U.S. Fish and Wildlife Service, Ecological Services, Phoenix, Arizona.

Huntoon, P.W. 1974. The karstic groundwater basins of the Kaibab Plateau, Arizona. Water Resources Research 10(3): 579-590.

Interagency Kanab Ambersnail Monitoring Team (IKAMT). 1998. The endangered Kanab ambersnail at Vaseys Paradise, Grand Canyon, Arizona: 1997 Final Report. Submitted to the Grand Canyon Monitoring and Research Center, Flagstaff, Arizona.

Jett, S.C. 1970. Biogeographical notes on the Kanab Canyon system, Mohave and Coconino Counties, Arizona. Plateau 43. Museum of Northern Arizona, Flagstaff.

Johnson, J. 1991. Biologists plot revenge in war of the snails. New Scientist 131(1783):14.

Johnson, P.W. and R.B. Sanderson. 1968. Spring flow into the Colorado River, Lees Ferry to Lake Mead, Arizona. Water Resources Report no. 34. Arizona State Land Department, Phoenix, Arizona.

Kerns, B.K. 1993. Alluvialchronology, malacology, and archaeology in middle Grand Gulch, southeast Utah. Master's Thesis. Northern Arizona University, Geology Department, Flagstaff.

Kubly, D.M. and G. Cole. 1979. The chemistry of the Colorado River and its tributaries in Marble and Grand Canyons. Proceedings of the First Conference on Scientific Research in the National Parks, Vol. 1: 565-572.

Lacy, R.C. 1987. Loss of genetic diversity from managed populations: interacting effects of drift, mutation, immigration, selection, and population subdivision. Conservation Biology 1:143-158.

LaCava, J., and J. Hughes. 1984. Determining minimum viable population levels. Wildlife Society Bulletin 12:370-376.

Leberg, P.L. 1990. Genetic considerations in the design of introduction programs. Transactions of the North American Wildlife and Natural Resources Conference 55:609-619.

Leberg, P.L. 1992. Effects of population bottlenecks on genetic diversity as measured by allozyme electrophoresis. Evolution 46:477-494.

Miller, M.P., J. Busch, and P. Keim. 1997. Genetic diversity, population structure, and relationships of the Kanab Amber Snail (*Oxyloma haydeni kanabensis*) and Hayden's Amber Snail (*Oxyloma haydeni haydeni*) in the southwest USA. Contract technical report to Arizona Game and Fish Department. Northern Arizona University, Department of Biological Sciences, Flagstaff.

Molloy, A.W. 1995. Studies on the endangered Chittenango ovate amber snail (*Novisuccinea chittenangoensis*) and related species of the Chittenango Creek watershed. Master's Thesis. College of Environmental Science and Forestry, State University of New York, Syracuse. 149 pp.

Pilsbry, H.A. 1948. Land Mollusca of North America. The Academy of Natural Sciences of Philadelphia Monographs II: 521-1113.

Reed, J.M., P.D. Doerr, and J.R. Walters. 1986. Determining minimum population sizes for birds and mammals. Wildlife Society Bulletin 14:255-261.

Reed, J.M., P.D. Doerr, and J.R. Walters. 1988. Minimum viable population size of the red-cockaded woodpecker. Journal of Wildlife Management 52:385-391.

Spamer, E.E. 1993. Late Pleistocene (?) land snails (mollusca: gastropoda) in "red earth" deposits of the Grand Canyon, Arizona. The Mosasaur 5: 47-58.

Spamer, E.E. and A.E. Bogan. 1993. Mollusca of the Grand Canyon and vicinity, Arizona: new and revised data on diversity and distributions, with notes on Pleistocene-Holocene mollusks of the Grand Canyon. Proceedings of the Academy of Natural Sciences of Philadelphia 144:21-68.

Sorensen, J.A. and D.M. Kubly. 1997. Investigations of the endangered Kanab ambersnail: monitoring, genetic studies, and habitat evaluation in Grand Canyon and northern Arizona. Nongame and Endangered Wildlife Program Technical Report 122. Arizona Game and Fish Department, Phoenix, Arizona.

Sorensen, J.A. and D.M. Kubly. 1998. Monitoring and habitat surveys of the endangered Kanab ambersnail in Grand Canyon and northern Arizona. Nongame and Endangered Wildlife Program Technical Report 125. Arizona Game and Fish Department, Phoenix, Arizona.

Stevens, L.E., F.R. Protiva, D.M. Kubly, V.J. Meretsky, and J.R. Petterson. 1997a. The ecology of Kanab ambersnail (Succineidae: *Oxyloma haydeni kanabensis* Pilsbry, 1948) at Vaseys Paradise, Grand Canyon, Arizona: Final Report. U.S. Bureau of Reclamation Glen Canyon Environmental Studies Program Report, Flagstaff.

Stevens, L.E., V.J. Meretsky, D.M. Kubly, J.C. Nagy, C. Nelson, J.R. Petterson, F.R. Protiva, and J.A. Sorensen. 1997b. The impacts of an experimental flood from Glen Canyon Dam on the endangered Kanab ambersnail at Vaseys Paradise, Grand Canyon, Arizona: Final Report. Grand Canyon Monitoring and Research Center, Flagstaff.

Stevens, L.E. and P.W. Price. 1998. Endangered Kanab ambersnail use of native and non-native host plants in Grand Canyon, Arizona: Draft 1997 Annual Technical and Administrative Report. NAU Project #BIO 351Z. Department of Biological Sciences, Northern Arizona University, Flagstaff.

U.S. Bureau of Reclamation (USBR). 1997. Progress Review - Implementation of the Glen Canyon Dam Operations Biological Opinion. December 5 memorandum to Field Supervisor, USFWS Arizona Ecological Services Office, Phoenix, from Regional Director, C.A. Calhoun, Salt Lake City. 6 pp.

U.S. Fish and Wildlife Service (USFWS). 1992. Endangered and threatened wildlife and plants, final rule to list the Kanab ambersnail as endangered. Federal Register 57 (75): 13657-13661.

USFWS. 1994. Biological Opinion on the Operation of Glen Canyon Dam. U.S. Fish and Wildlife Service, Denver, Colorado.

USFWS. 1995. Kanab ambersnail (*Oxyloma haydeni kanabensis*) recovery plan. U.S. Fish and Wildlife Service, Denver, Colorado. 21 pp.

USFWS. 1996. Biological Opinion on the effects of the Spring 1996 Beach/Habitat-Building Flow, Glen Canyon Dam. U.S. Fish and Wildlife Service, Denver, Colorado.

USFWS. 1997. Biological Opinion on the November 1997 Fall Test Flow from Glen Canyon Dam. U.S. Fish and Wildlife Service, Denver, Colorado.

APPENDIXES

Appendix A. Survey sites and suitability categories.

KAS Site: Vaseys Paradise
KAS Site: Three Lakes, Utah

Site 1: "KeyHole Spring" (Optimum Habitat)
2: Lower Deer Creek Spring (More Desirable Habitat)
3: Upper Elves Chasm (Acceptable Habitat)
4: Lower Ribbon Falls (More Desirable Habitat)
5: 147.8 mile RR Seep (More Desirable Habitat)
6: Showerbath Spring (More Desirable Habitat)
7: Saddle Canyon (More Desirable Habitat)
8: Thunder River (Optimum Habitat)
9: Roaring Springs (Optimum Habitat)
10: Upper Deer Creek Spring (More Desirable Habitat)
11: Santa Maria Spring (More Desirable Habitat)
12: Dripping Spring (More Desirable Habitat)
13: Nankoweap "Canyon Grape Spring" (Acceptable Habitat)
14: Kanab Creek Seep (Acceptable Habitat)
15: Nankoweap "Twin Springs" (Acceptable Habitat)

KAS Site: Vaseys Paradise

Description: dilute dolomitic spring with several large waterfalls and densely vegetated slopes.[1]

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: June 16 & July 19, 1996; Mar 18, 1997

Site Aspect: east
Solar Exposure: early AM to early PM (Mar-Oct)
Annual BTUs/sq ft: 287,603

Water Discharge (m^3/s): 0.004-0.28 range[2, 3, 4, 5, 6]
Historic Max Discharge: unknown
Water Temp (• C): 15.9 (min/max 12.0-18.0)[4, 6, 7, 8]

Conductivity (µS): 308 (min/max 180-408)[4, 6, 7, 8]
Water pH: 8.1 median (min/max 7.4-8.3)[4, 6, 7, 8]

Natural Disturbance Potential: low
Natural Impact Evidence: flood debris and scoured vegetation in lower habitat
Other Disturbances: minor beaver damage to veg

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 31.8 RR (51.2 km)
Elevation: 880 m
UTM: N4039300, E423300
7.5min Topo Quad: Tatahatso Point

Accessibility: easy--boat or hike

Geologic Strata: Redwall Limestone
Predominant Substrate: soil/loam
Litter/Duff: high density

Soil Temp (• C): 20.2 median (min/max 10.5-26.0)
Soil Moisture (% sat): 100 med (min/max 20-100)
Soil pH: 6.9 median (min/max 5.7-7.2)
Soil Depth (cm): 5.5 median (min/max 0-15)
Slope (degrees): 26 median (min/max 8-65)

Estimated Recreational Use: moderate
Recreation Impact Evidence: minor trampled veg
NPS Recreation Estimate: 20 visitors/day[9]

Primary Vegetation & Estimated Area: *Mimulus cardinalis* and *Nasturtium officinale* (• 900 m^2 combined)[2]

Associated Vegetation: *Adiantum capillus-veneris, Artemesia ludoviciana, Brickellia longifolia, Bromus wildenowii, Carex aquatilis, Ceris occidentalis, Dichanthelium lanuginosum, Elymus canadensis, Epipactus gigantea, Equisetum* spp., *Juncus* spp., *Lobelia cardinalis, Phragmites australis, Plantago lanceolata, Polygonum amphibium, Salix exiqua, S. gooddingii, Tamarix ramosissima, Toxicodendron rydbergii* [2, 10]

Mollusks: succineids--*Oxyloma haydeni kanabensis* (Kanab ambersnail)[2, 3, 11-15], *Catinella* (sp. undescribed), *C. avara, C. vermeta*; physids--*Physa* (=*Physella*) spp.; limnaeids--*Fossaria obrussa*; zonitids--*Hawaiia minuscula*; limacids--*Deroceras laeve*[2, 3]

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha laboriosa*, Salticidae, Pseudoscorpiones *Dactylochelifer* sp.; oligochaetes--*Lumbriculus* sp.; planarians--*Dugesia* sp.; trematodes--*Leucochloridium cyanocittae*; coleopterans--Buprestidae *Acmaeodera pulchella*, Carabidae *Bembidion* sp., Coccinellidae *Hippodamia convergens*, Hydrophilidae; collembolids; dipterans--Chironomidae *Calospectra* sp., Diamesinae, Empididae, Muscidae *Stomoxys* sp., Simuliidae, Stratiomyiidae *Euparyphus* sp., Tabanidae *Chrysops* sp., Tachinidae, Tipulidae *Tipula* sp.; emphemeropterans--*Baetis* spp.; hemipterans--Reduviidae, Veliidae *Microvelia* sp.; homopterans--Aphididae, Cicadidae *Diceroprocta apache*; hymenopterans--Apidae, Pompilidae *Pepsis chrysothermis*, Sphecidae *Sceliphron caemon tarium*; lepidopterans--Danaidae *Danaus plexippus*, Nymphalidae *Nymphalis antiopa, Paragyractis* sp., Sphingidae *Hylas linneata*; odonatids--Coenagrionidae, Libellulidae *Libellula saturata*; orthopterans--Gryllidae, Tettigoniidae; trichopterans--Helicopsychidae *Helicopsyche* sp., Hydropsychidae[2, 8]

KAS Site: Vaseys Paradise (continued)

Site Status: Only known population of KAS in Arizona. Threatened by high flow releases (>30,000 cfs stage) from Glen Canyon Dam. Two types of primary vegetation; both abundant. Presence of poison ivy keeps most visitors out of vegetated areas.

KAS Conservation Recommendation: Probable source of KAS for establishment sites.

References: [1]Kubly and Cole 1979; [2]Stevens et al. 1997b; [3]Spamer and Bogan 1993; [4]Johnson and Sanderson 1968; [5]Huntoon 1974; [6]Foust and Hoppe 1985; [7]unpublished NPS data (Rihs 1996); [8]Cole and Kubly 1976; [9]unpublished NPS data (Jalbert 1997); [10]Clover and Jotter 1944; [11]Clarke 1991; [12]USFWS 1992; [13]USFWS 1995; [14]Stevens et al. 1997a; [15]Miller et al. 1997.

KAS Site: Three Lakes

Description: wet meadow at base of sandstone cliffs, marsh and pond in southern area.

Jurisdiction: Privately owned land and water rights

Surveyed: October 3, 1996

Site Aspect: east
Solar Exposure: early AM to last PM (Jan-Dec)
Annual BTUs/sq ft: 521,003

Water Discharge (m^3/s): low (standing water)
Historic Max Discharge: unknown
Water Temp (• C): 9.0
Conductivity (µS): 540
Water pH: unknown

Natural Disturbance Potential: low
Natural Impact Evidence: minor flash flood debris
Other Disturbances: previous livestock grazing and trampling; future commercial development planned

Location: 10 km northwest of Kanab
Kane County, Utah
Specific: west side of Hwy 89
Elevation: 1692 m
UTM: N4108350, E360900
7.5min Topo Quad: Kanab

Accessibility: difficult--auto (landowner permission)

Geologic Strata: Navajo Sandstone
Predominant Substrate: soil/loam
Litter/Duff: medium density

Soil Temp (• C): 8.5 median (min/max 7.5-12.0)
Soil Moisture (% sat): 100 med (min/max 95-100)
Soil pH: 7.0 median (min/max 6.9-7.2)
Soil Depth (cm): 20 median (min/max 12-20)
Slope (degrees): 0 median (min/max 0-5)

Estimated Recreational Use: none
Recreation Impact Evidence: minor trampled veg and minor litter

Primary Vegetation & Estimated Area: *Typha domingensis* (>50 m^2) and *Nasturtium* spp. (<2 m^2)

Associated Vegetation: *Carex aquatilis, Eleocharis* spp., *Epilobium* spp., *Galus* spp., *Junus balticus, Polygonum* spp., *Rosa woodsei, Rumex crispus, Salix lutea, Vinca* spp.[1]

Mollusks: succineids--*Oxyloma haydeni kanabensis* (Kanab ambersnail)[1-6], undescribed succineid shell; physids--*Physa* (=*Physella*) spp.; limnaeids--*Fossaria obrussa*; undescribed small bivalve

Other Invertebrates: (no collections, observation only) dipterans--Calliphoridae; hymenopterans--Formicidae; orthopterans--Acrididae (?); trematodes--*Leucochloridium* (?)[7]

Site Status: Only known KAS population in Utah. Abundant primary vegetation. Low vulnerability to natural or recreational impacts. Historically, area has received flash flood damage, livestock trampling, and loss of habitat by commercial development--more development is planned.

KAS Conservation Recommendation: Negotiate conservation agreement or land acquisition (including secured water rights) with private landowner. Possible source of KAS for establishment sites (with permission of landowner).

References: [1]Clarke 1991; [2]USFWS 1992; [3]Spamer and Bogan 1993; [4]USFWS 1995; [5]Stevens et al. 1997b; [6]Miller et al. 1997; [7]pers. comm. V. Meretsky (1998).

Site 1: "KeyHole Spring"[1]

Description: small, wet spring with dense vegetation and multiple terraces.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Apr 11, 1997; Feb 19, Mar 13 and May 11, 1998

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 47.1 RR (75.8 km)
Elevation: 900 m
UTM: N4024308, E420484
7.5min Topo Quad: Point Imperial

Accessibility: easy--boat and hike

Site Aspect: northeast
Solar Exposure: early AM to mid-day (Apr-Sep)
Annual BTUs/sq ft: 207,741

Geologic Strata: Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: medium density

Water Discharge (m^3/s): low
Historic Max Discharge: unknown
Water Temperature (• C): 11.2
Specific Conductivity (µS): 350
Water pH: 6.5

Soil Temp (• C): 10.1 median (min/max 10.0-11.2)
Soil Moisture (% sat): 98 med (min/max 82-100)
Soil pH: 6.5 median (min/max 6.1-6.6)
Soil Depth (cm): 15 median (min/max 6.5-15)
Slope (degrees): 14 median (min/max 2-31)

Natural Disturbance Potential: low
Natural Impact Evidence: minor rockfall
Other Disturbances: none

Estimated Recreational Use: none
Recreation Impact Evidence: none
NPS Recreation Estimate: unknown

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (15-25 m²) and *Typha* spp. (1 m²)

Associated Vegetation: *Adiantum capillus-veneris, Aquilegia chrysantha, Carex* spp., *Ceris occidentalis, Cladium californicum, Salix exigua,* giant thistle (undescribed sp.)

Mollusks: succineids--*Catinella vermeta*[2]; physids--*Physa* (=*Physella*) spp.; limacids--*Deroceras* sp.

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha* sp.; dipterans--Tipulidae *Tipula* sp.; hymenopterans--Formicidae

Other Notable Fauna: mule deer (*Odocoileus hemionus*) on site during visit

Site Status: Protected from most natural impacts, no recreation use, and sufficient amount of primary vegetation. Access via existing game trails.

KAS Establishment Recommendation: Optimum habitat.

References: [1]pers. comm. D. Pratley (1997); [2]identified by J. Hoffman (1997).

Site 2: Lower Deer Creek Spring

Description: Wet spring along densely vegetated talus slope and floodplain (707 m^3/s stage) marsh.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jul 28 and Nov 3, 1996; Mar 19 and May 18, 1998

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 136.1 RR (219.0 km)
Elevation: 591 m
UTM: N4027916, E364729
7.5min Topo Quad: Fishtail Mesa

Accessibility: easy--boat

Site Aspect: south
Solar Exposure: early AM to late PM (Jan-Dec)
Annual BTUs/sq ft: 535,088

Geologic Strata: Tapeats Sandstone
Predominant Substrate: soil/loam
Litter/Duff: medium density

Water Discharge (m^3/s): moderate
Historic Max Discharge: unknown
Water Temp (• C): 17.6 med (min/max 16.0-19.1)
Conductivity (µS): 910 med (min/max 820-1000)
Water pH: unknown

Soil Temp (• C): 24.0 median (min/max 13.0-25.0)
Soil Moisture (% sat): 97 med (min/max 90-100)
Soil pH: 6.6 median (min/max 6.0-6.8)
Soil Depth (cm): 19 median (min/max 15-20)
Slope (degrees): 7 median (min/max 1-10)

Natural Disturbance Potential: moderate
Natural Impact Evidence: flash flood debris in floodplain marsh (from March 1996 flood)
Other Disturbances: none

Estimated Recreational Use: none
Recreation Impact Evidence: minor trampled veg
NPS Recreation Estimate: 100-200 visitors/day at the riverside waterfall and slot canyon[1]--unlikely to visit spring (3 m below trail, ringed by poison ivy)

Primary Vegetation & Estimated Area: *Typha* spp. (>20 m^2), *Nasturtium* spp. (>20 m^2), and *Mimulus gluttatus* (10 m^2), *Mimulus cardinalis* (on upper slope >60 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Carex* spp., *Equisetum* spp., *Juncus* spp., *Scirpus* spp., *Phragmites australis, Populus fremontii, Salix exigua, Toxicodendron rydbergii*

Mollusks: succineids--*Catinella* spp.; physids--*Physa* (=*Physella*) spp.[2]

Other Invertebrates: arachnids--(undescribed sp.); homopterans--(undescribed leafhopper sp.); hymenopterans; lepidopterans--Papilionidae *Papilio*; odonatids--Aeshnidae *Anax junius*, Coenagrionidae;

Site Status: Floodplain marsh threatened by high flow releases from Glen Canyon Dam, but vegetated slope is protected from natural and recreational impacts. Has three types of primary vegetation in abundance, but lacking a diverse invertebrate community. Presence of poison ivy keeps visitors out of spring habitat.

KAS Establishment Recommendation: More desirable habitat.

References: [1]unpublished NPS data (Jalbert 1997); [2]Stevens et al. 1997.

Site 3: Upper Elves Chasm (above sawgrass patch)

Description: large hanging gardens, plunge pools, waterfalls, and streamside vegetation.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: April 16, 1997

Site Aspect: northeast
Solar Exposure: mid-day (Apr-Aug)
Annual BTUs/sq ft: 77,633

Water Discharge (m^3/s): 0.002-0.02 range[1, 2, 3]
Historic Max Discharge: unknown
Water Temp (• C): 16.3 (min/max 8.0-21.5)[1, 2, 4]
Conductivity (µS): 780 (min/max 620-1050)[1, 2, 4, 5]
Water pH: 8.2 median (min/max 6.7-9.0)[1, 2, 4, 5]

Natural Disturbance Potential: moderate
Natural Impact Evidence: flash flood debris, minor rockfall, and downed/scoured veg
Other Disturbances: none

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 116.6 RL (187.6 km)
Elevation: 902 m
UTM: N4005750, E369300
7.5min Topo Quad: Explorers Monument

Accessibility: difficult--boat, hike, and climb

Geologic Strata: Bright Angel Shale
Predominant Substrate: soil/loam
Litter/Duff: high density

Soil Temp (• C): 11.0 median (min/max 10.0-13.5)
Soil Moisture (% sat): 79 med (min/max 65-100)
Soil pH: 6.7 median (min/max 6.5-7.1)
Soil Depth (cm): 15 median (min/max 1.5-15)
Slope (degrees): 14 median (min/max 8-30)

Estimated Recreational Use: low
Recreation Impact Evidence: minor trampled veg
NPS Recreation Estimate: 50-70 visitors/day (lower area)[6]; upper area maybe 5-7 visitors/day[7]

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (>200 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Aquilegia chrysantha, Carex* spp., *Ceris occidentalis, Cladium californicum*, moss spp.

Mollusks: none

Other Invertebrates: arachnids--(undescribed sp.); coleopterans--Scarabaeidae; dipterans--Chironomidae, Simuliidae

Site Status: Streamside veg threatened by flash flood impact, but hanging gardens & primary vegetation on upper slopes probably protected. Upper area not visited by many hikers due to restricted access--climbing necessary.[7]

KAS Establishment Recommendation: Acceptable habitat.

References: [1]Johnson and Sanderson 1968; [2]unpublished NPS data (Rihs 1996); [3]Spamer and Bogan 1993; [4]Cole and Kubly 1976; [5]Foust and Hoppe 1985; [6]unpublished NPS data (Jalbert 1997); [7]pers. comm. D. Pratley (1997).

Site 4: Lower Ribbon Falls

Description: vegetated travertine mound at the base of a large waterfall, sheltered in an overhang.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Aug 23, 1996; Jun 4, 1997; June 9, 1998

Site Aspect: east
Solar Exposure: mid AM to mid-day (not May-Jul)
Annual BTUs/sq ft: 127,153

Water Discharge (m^3/s): 0.01-0.07 range[1, 2]
Historic Max Discharge: unknown
Water Temp (• C): 16.0 med (min/max 6.0-22.0)[2, 3]

Conductivity (µS): 409 med (min/max 260-610)[2, 3]
Water pH: 8.4 median (min/max 8.1-8.9)[2, 3]

Natural Disturbance Potential: low
Natural Impact Evidence: minor flash flood debris only along stream drainage
Other Disturbances: none

Location: Grand Canyon, backcountry
Coconino County, Arizona
Trail: North Kaibab Trail
Elevation: 1158 m
UTM: N4001950, E405250
7.5min Topo Quad: Bright Angel Point

Accessibility: moderate--hike

Geologic Strata: Temple Butte/Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: medium density

Soil Temp (• C): 18.5 median (min/max 16.5-19.0)
Soil Moisture (% sat): 80 med (min/max 55-100)
Soil pH: 6.8 median (min/max 6.2-7.0)
Soil Depth (cm): 8 median (min/max 0-20)
Slope (degrees): 28 median (min/max 3-90)

Estimated Recreational Use: moderate
Recreation Impact Evidence: minor trampled veg, worn trails, minor litter
NPS Recreation Estimate: unknown[4]--popular stop for hikers between Phantom Ranch & North Rim

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (>30 m^2) and *Nasturtium* spp. (• 5 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Aquilegia chrysantha, Carex* spp., *Salix exigua, Tamarix ramosissima*, small thistle spp., moss spp.

Mollusks: succineids--*Catinella* spp.[5]

Other Invertebrates: arachnids--(two undescribed spp.); isopods--Armadillidiidae *Armadillidium vulgare*; oligochates--*Lumbriculus*; dipterans--Simullidae; coleopterans--Carabidae; hemipterans--Gerridae; homopterans--(undescribed sp.); hymenopterans--Apidae; megalopterans--Corydalidae; odonatids--Coenagrionidae, Libellulidae

Site Status: Low vulnerability to natural disturbance due to overhang, but recreational impact may be higher. NPS has placed "Reveg Area-Keep Out" signs throughout area to secure large patches of primary vegetation.

KAS Establishment Recommendation: More desirable habitat.

References: [1]Huntoon 1974; [2]unpublished NPS data (Rihs 1996); [3]Foust and Hoppe 1985; [4]unpublished NPS data (Jalbert 1997); [5]Stevens et al. 1997b.

Site 5: 147.8 mi RR Seep

Description: large, travertine seep with marsh at base and dense vegetation above.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jul 28, 1996; Apr 18, 1997; Mar 20 and May 19, 1998

Location: Grand Canyon, river corridor
Mohave County, Arizona
River Mile: 147.8 RR (237.8 km)
Elevation: 585 m
UTM: N4023876, E350129
7.5min Topo Quad: Havasu Falls

Accessibility: easy--boat

Site Aspect: south
Solar Exposure: mid AM to mid PM (Jan-Dec)
Annual BTUs/sq ft: 382,419

Geologic Strata: Muav Limestone
Predominant Substrate: sand/loam
Litter/Duff: medium density

Water Discharge (m^3/s): low
Historic Max Discharge: unknown
Water Temp (• C): 26.5 med (min/max 23.0-30.0)
Conductivity (µS): 1540 med (1130-1950)
Water pH: unknown

Soil Temp (• C): 27.0 median (min/max 24.0-32.0)
Soil Moisture (% sat): 100 median (0 range)
Soil pH: 5.7 median (min/max 5.2-6.9)
Soil Depth (cm): 7 median (min/max 0-15)
Slope (degrees): 18 median (min/max 3-55)

Natural Disturbance Potential: low
Natural Impact Evidence: minor rockfall and some flood scoured upper veg (1997 season)
Other Disturbances: none

Estimated Recreational Use: none
Recreation Impact Evidence: none
NPS Recreation Estimate: unknown

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (20 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Aquilegia chrysantha, Baccharis* spp., *Carex* spp., *Ceris occidentalis, Cladium californicum, Equisetum* spp., *Phragmites australis, Salix exigua, Tamarix ramosissima*, moss spp.

Mollusks: succineids--*Catinella* spp.[1]; physids--*Physa* (=*Physella*) spp.; zonitids--*Hawaiia minuscula*[1]

Other Invertebrates: arachnids (unknown spp.); dipterans (various spp.); hemipterans---Veliidae *Rhagovelia* sp.; lepidopterans--Papilionidae *Papilio* spp.; odonatids--Libellulidae *Libellula saturata*

Other Notable Fauna: Grand Canyon rattlesnake (*Crotalus viridis abyssus*) on site during April 1997 visit[2]

Site Status: Low vulnerability to natural or recreational impacts. Low diversity of invertebrate community.

KAS Establishment Recommendation: More desirable habitat.

References: [1]Stevens et al. 1997; [2]pers. comm. B. Helin (1997).

Site 6: Showerbath Spring

Description: large spring/travertine hanging garden, densely vegetated, 3 m above stream drainage.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: November 20, 1996

Site Aspect: northwest
Solar Exposure: mid-day to late PM (Jan-Dec)
Annual BTUs/sq ft: 251,252

Water Discharge (m^3/s): moderate
Historic Max Discharge: unknown
Water Temp (• C): 18.0
Conductivity (µS): 1070
Water pH: unknown

Natural Disturbance Potential: low
Natural Impact Evidence: flash flood debris 2.1 m high in stream channel and minor rockfall
Other Disturbances: none

Location: Grand Canyon/Kanab Creek backcountry
Coconino County, Arizona
Specific: 12.9 km upstream, Kanab Creek
Elevation: 835 m
UTM: N4035700, E353000
7.5min Topo Quad: Kanab Point

Accessibility: difficult--overnight hike and climbing

Geologic Strata: Muav Limestone
Predominant Substrate: bedrock
Litter/Duff: medium density

Soil Temp (• C): unknown (veg patch inaccessible)
Soil Moisture (% sat): (100 estimated)
Soil pH: unknown
Soil Depth (cm): unknown
Slope (degrees): 55

Estimated Recreational Use: low
Recreation Impact Evidence: campsite opposite
NPS Recreation Estimate: unknown

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (• 40 m^2)

Associated Vegetation: *Imperata brevifolia, Phragmites australis, Thelypteris puberula sonorensis*,[1] moss spp.

Mollusks: physids--*Physa virgata* (=*Physella virgata*)[2] from creek

Other Invertebrates: arachnids--(undescribed sp.); ephemeropterans; hemipterans--Veliidae *Rhagovelia* sp.; hymenopterans--Pompilidae *Pepsis chrysothermis*; odonatids--Libellulidae *Libellula saturata*

Site Status: Abundant primary vegetation on top of travertine shelf; protected from even large flash floods. Low vulnerability to natural or recreational impacts. Vegetation inaccessible without technical climbing gear. Requires 1-1.5 days of hiking to reach site from Hack Canyon trailhead or Kanab Creek/Colorado River confluence.

KAS Establishment Recommendation: More desirable habitat.

References: [1]Jett 1970; [2]identified by J. Landye (1996).

Site 7: Saddle Canyon

Description: several hanging gardens and extensive streamside vegetation with open tree canopy.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jun 18, 1996; Apr 10, 1997; Feb 19, Mar 12, and May 11, 1998

Site Aspect: north
Solar Exposure: mid-day to early PM (Mar-Oct)
Annual BTUs/sq ft: 114,463

Water Discharge (m^3/s): 0.003-0.006 range[1]
Historic Max Discharge: unknown
Water Temp (• C): 16.0 med (min/max 10.5-21.7)[1]
Conductivity (µS): 396 med (min/max 320-427)[1]
Water pH: 8.5 median (min/max 7.9-8.8)[1]

Natural Disturbance Potential: moderate
Natural Impact Evidence: minor rockfall and flash flood debris (1997 season)
Other Disturbances: none

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 47.0 RR (75.6 km)
Elevation: 976 m
UTM: N4024050, E418850
7.5min Topo Quad: Point Imperial

Accessibility: easy--boat and hike

Geologic Strata: Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: low density

Soil Temp (• C): 16.0 median (min/max 9.9-26.0)
Soil Moisture (% sat): 81 med (min/max 55-100)
Soil pH: 6.7 median (min/max 6.1-6.9)
Soil Depth (cm): 9 median (min/max 4-15)
Slope (degrees): 10 median (min/max 2-28)

Estimated Recreational Use: high
Recreation Impact Evidence: trampled veg and worn trails
NPS Recreation Estimate: 75-80% of all trips, or about 350 visitors/week (extrapolated)[2]

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (>200 m^2)

Associated Vegetation: *Acer negundo, Adiantum capillus-veneris, Carex* spp., *Celtis reticulata, Ceris occidentalis, Salix exigua*, giant thistle (undescribed sp.)

Mollusks: succineids--*Catinella avara*[3]; limacids--*Deroceras laeve*[4]

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha* sp.; dipterans---Asilidae, Muscidae; hemipterans--Gerridae *Gerris remigis*, Veliidae *Rhagovelia* sp.; hymenopterans--Apidae; lepidopterans; odonatids--Coenagrionidae, Libellulidae *Libellula saturata*; orthopterans--Gryllidae; trichopterans

Site Status: Possible moderate recreation and flash flood impact to streamside vegetation, however, there is abundant primary vegetation and an invertebrate community with high species richness and diversity.

KAS Establishment Recommendation: More desirable habitat.

References: [1]unpublished NPS data (Rihs 1996); [2]unpublished NPS data (Jalbert 1997); [3]Spamer and Bogan 1993; [4]identified by J. Hoffman (1997).

Site 8: Thunder Spring

Description: large dolomitic spring with numerous waterfalls, vegetated terraces, & open tree canopy.[1]

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jul 27, 1996; Apr 17, 1997; Feb 23 and Mar 18, 1998

Site Aspect: southeast
Solar Exposure: early AM to mid PM (Jan-Dec)
Annual BTUs/sq ft: 584,225

Water Discharge (m^3/s): 0.47-0.59 range[2, 3, 4]
Historic Max Discharge: 3.59 m^3/s spring flood[2, 3]
Water Temp (• C): 12.7 (min/max 11.0-16.0)[2, 5, 6]
Conductivity (µS): 307 (min/max 220-326)[2, 5, 6]
Water pH: 8.4 median (min/max 7.7-8.6)[2, 5, 6]

Natural Disturbance Potential: low
Natural Impact Evidence: minor rockfall
Other Disturbances: none

Location: Grand Canyon, backcountry
Coconino County, Arizona
Specific: Thunder River/Tapeats Creek
Elevation: 1000 m
UTM: N4028650, E369350
7.5min Topo Quad: Tapeats Amphitheater

Accessibility: moderate--boat and hike, or helo

Geologic Strata: Temple Butte/Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: high density

Soil Temp (• C): 17.0 median (min/max 12.0-21.0)
Soil Moisture (% sat): 67.5 med (min/max 0-100)
Soil pH: 7.0 median (min/max 6.4-7.6)
Soil Depth (cm): 10 median (min/max 0-15)
Slope (degrees): 36 median (min/max 5-74)

Estimated Recreational Use: moderate
Recreation Impact Evidence: minor trampled veg
NPS Recreation Estimate: 16,000 usernights/year and limit 35 campers/night in the lower area campground[7]

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (>200 m^2) and *Nasturtium* spp. (>20 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Carex* spp., *Ceris occidentalis, Equisetum* spp., *Phragmites australis, Populus fremontii, Salix gooddingii*, mint spp., moss spp.

Mollusks: succineids--*Catinella avara*; oreohelicids--*Oreohelix strigosa depressa*; limacids--*Deroceras laeve*; helminthoglyptids--*Sonorella coloradoensis*; cochlicopids--*Cionella lubrica*; discids--*Discus cronkhitei*; zonitids--*Glyphyalinia indentata, Zonitoides arboreus*[4, 8]

Other Invertebrates: arachnids--Salticidae; isopods--Armadillidiidae *Armadillidium vulgare*; dipterans--Simuliidae; coleopterans--Carabidae, Hydrophilidae; ephemeropterans; hemipterans--Reduviidae (Emesinae); hymenopterans--Formicidae *Pogonomyrmex* spp.; megalopterans--Corydalidae; odonatids--Coenagrionidae, Libellulidae; plectopterans; trichopterans

Site Status: Two types of primary vegetation in high abundance. Low vulnerability to natural and recreational impacts--most primary vegetation on the opposite side of the spring drainage and generally inaccessible. Site supports high species richness and diversity of mollusks and other invertebrates.

KAS Establishment Recommendation: Optimum habitat.

References: [1]Kubly and Cole 1979; [2]Johnson and Sanderson 1968; [3]Huntoon 1974; [4]Spamer and Bogan 1993; [5]Foust and Hoppe 1985; [6]unpublished NPS data (Rihs 1996); [7]unpublished NPS data (Jalbert 1997); [8]Stevens et al. 1997b.

Site 9: Roaring Springs

Description: three large springs with terraced waterfalls, pools, dense veg, and dense tree canopy.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Aug 22, 1996; Jun 4, 1997; June 9, 1998

Site Aspect: southeast
Solar Exposure: mid AM to mid PM (Jan-Dec)
Annual BTUs/sq ft: 374,297

Water Discharge (m^3/s): 0.16-0.37 range[1, 2, 3]
Historic Max Discharge: unknown
Water Temp (• C): 12.0 (min/max 9.0-14.0)[2, 3, 4]
Conductivity (µS): 295 (min/max 180-310)[2, 3, 4]
Water pH: 8.2 median (min/max 7.7-8.7)[2, 3, 4]

Natural Disturbance Potential: low
Natural Impact Evidence: minor flash flood debris
Other Disturbances: rest houses and corrals, water pipes

Location: Grand Canyon, backcountry
Coconino County, Arizona
Trail: North Kaibab Trail
Elevation: 1570 m
UTM: N4006077, E406809
7.5min Topo Quad: Bright Angel Point

Accessibility: moderate--hike or helo

Geologic Strata: Redwall/Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: medium density

Soil Temp (• C): 16.0 median (min/max 13.0-20.8)
Soil Moisture (% sat): 100 med (min/max 48-100)
Soil pH: 7.0 median (min/max 6.6-7.2)
Soil Depth (cm): 6 median (min/max 3-20)
Slope (degrees): 15 median (min/max 5-44)

Estimated Recreational Use: high
Recreation Impact Evidence: trampled veg, worn trails, and minor litter
NPS Recreation Estimate: likely 100+ visitors/day[5]

Primary Vegetation & Estimated Area: *Nasturtium* spp. (>50 m^2), *Mimulus gluttatus* (>10 m^2), and *Typha* spp. (>15 m^2)

Associated Vegetation: *Acer negundo, Adiantum capillus-veneris, Carex* spp., *Equisetum* spp., *Phragmites australis, Populus fremontii, Quercus gambelii, Vitis arizonica,* moss spp.

Mollusks: succineids--*Catinella* sp., cochlicopids--*Cochlicopa*, oreohelicids--*Oreohelix,* zonitids--*Hawaiia, Strobilops* or *Euconulus*, *Anguispira, Columella* or *Gastrocopta* or *Vertigo*[6]

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha* sp.; isopods--Armadillidiidae *Armadillidium vulgare*; dipterans--Calliphoridae; coleopterans--Carabidae, Coccinellidae *Hippodamia convergens*; hemipterans--Gerridae *Gerris remigis*; homopterans--Cicadidae *Diceroprocta apache*; hymenopterans--Formicidae, Sphecidae *Bembix* sp., Vespidae *Polistes* sp.; lediopterans--Papilionidae *Papilio* spp.; odonatids--Aeshnidae *Anax junius*, Calopterygidae (=Agrionidae) *Hetaerina* sp., Coenagrionidae, Libellulidae *Libellula saturata*; orthopterans--Gryllidae, Tettigoniidae

Site Status: Low vulnerability to natural disturbance, but recreation impacts are higher. Most visitors stay out of large vegetation patches and those on the upper terraces. Two types of primary vegetation, both in abundance. Invertebrate community has very high species richness and diversity. Water piped to both rim resorts/lodges.

KAS Establishment Recommendation: Optimum habitat.

References: [1]Huntoon 1974; [2]Johnson and Sanderson 1968; [3]unpublished NPS data (Rihs 1996); [4]Foust and Hoppe 1985; [5]unpublished NPS data (Jalbert 1997); [6]pers. comm. E. North (1998).

Site 12: Upper Deer Spring (aka Deer Spring)

Description: dilute dolomitic spring, waterfall, and shallow pool, sheltered in a narrow side canyon.[1]

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Juy 28, 1996; Apr 17, 1997; Feb 23, Mar 19, and May 18, 1998

Site Aspect: west
Solar Exposure: late AM to late PM (Jan-Dec)
Annual BTUs/sq ft: 483,755

Water Discharge (m^3/s): high (provides • ¼ water for Deer Creek drainage--0.14-0.46 range)[2, 3, 4, 5, 6]
Historic Max Discharge: 8.4 m^3/s (Deer Creek)[6, 8]
Water Temp (• C): 15.3 (min/max 9.5-18.6)[2, 4, 5, 7]
Conductivity (µS): 348 (min/max 260-425)[2, 4, 5, 7]
Water pH: 8.4 median (min/max 7.1-9.1)[2, 4, 5, 7]

Natural Disturbance Potential: low
Natural Impact Evidence: minor flash flood debris and minor rockfall
Other Disturbances: wildfire damage in lower valley

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 136.1 RR (218.9 km)
Elevation: 830 m
UTM: N4029168, E365341
7.5min Topo Quad: Fishtail Mesa

Accessibility: easy--boat and hike

Geologic Strata: Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: none

Soil Temp (• C): 18.5 median (min/max 16.0-20.0)
Soil Moisture (% sat): 100 med (min/max 45-100)
Soil pH: 6.7 median (min/max 6.4-7.0)
Soil Depth (cm): 6 median (min/max 3-22)
Slope (degrees): 8 median (min/max 3-30)

Estimated Recreational Use: moderate
Recreation Impact Evidence: minor trampled veg, worn trails, and minor litter
NPS Recreation Estimate: 100-200 visitors/day at the riverside waterfall and slot canyon, less at the spring[9]

Primary Vegetation & Estimated Area: *Nasturtium* spp. (>35 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Baccharis* spp., *Brickellia longifolia, Ceris occidentalis, Salix exigua*, moss spp.

Mollusks: succineids--*Catinella* spp.[10]; physids--*Physa* (=*Physella*) spp.

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha* sp.; coleopterans--Hydrophilidae; dipterans--(undescribed sp.); ephemeropterans; hemipterans--Veliidae *Rhagovelia* sp.; odonatids--Coenagrionidae, Libellulidae; plecopterans

Site Status: Canyon walls and closed canopy of redbud trees shelter pool and streamside habitat from harsh afternoon sun and severe weather. Some trampled veg, but most visitors stay out of lower vegetated areas.

KAS Establishment Recommendation: More desirable habitat.

References: [1]Kubly and Cole 1979; [2]Johnson and Sanderson 1968; [3]Huntoon 1974; [4]unpublished NPS data (Rihs 1996); [5]Foust and Hoppe 1985; [6]Spamer and Bogan 1993; [7]Cole and Kubly 1976; [8]Cooley et al. 1977; [9]unpublished NPS data (Jalbert 1997); [10]Stevens et al. 1997b.

Site 11: Santa Maria Spring

Description: wet talus seep with a water trough at the base (water source for hikers).

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Mar 31, 1997; Jan 27, 1998

Site Aspect: southwest
Solar Exposure: mid AM to late PM (Jan-Dec)
Annual BTUs/sq ft: 584,203

Water Discharge (m^3/s): low
Historic Max Discharge: unknown
Water Temp (• C): 10.0
Conductivity (µS): 410
Water pH: unknown

Natural Disturbance Potential: low
Natural Impact Evidence: minor rockfall
Other Disturbances: none

Location: Grand Canyon, backcountry
Coconino County, Arizona
Trail: South Hermit Trial
Elevation: 1531 m
UTM: N3991100, E390010
7.5min Topo Quad: Grand Canyon

Accessibility: moderate--hike

Geologic Strata: Supai Group (?)
Predominant Substrate: soil/loam
Litter/Duff: high density

Soil Temp (• C): 12.0 median (min/max 9.5-13.0)
Soil Moisture (% sat): 100 med (min/max 70-100)
Soil pH: 7.0 median (min/max 6.8-7.1)
Soil Depth (cm): 6.5 median (min/max 1.5-7)
Slope (degrees): 32 median (min/max 12-45)

Estimated Recreational Use: moderate
Recreation Impact Evidence: moderate trampled veg and minor litter
NPS Recreation Estimate: rest house for hikers (no camping), whole area has limit 29 campers/night[1]

Primary Vegetation & Estimated Area: *Typha* spp. (>30 m^2)

Associated Vegetation: *Carex* spp., *Juncus* spp., moss spp., various grass spp., thistle spp.

Mollusks: none

Other Invertebrates: arachnids--(two undescribed spp.), Acarina; chilopods; isopods--Armadillidiidae *Armadillidium vulgare*; collembolids; oligochates--*Lumbriculus*; coleopterans; dipterans--Simuliidae; hymenopterans--Formicidae; lepidopterans; odonatids--Coenagrionidae

Site Status: Low vulnerability to natural disturbance, but recreational impacts may be higher. Primary vegetation is abundant.

KAS Establishment Recommendation: More desirable habitat.

References: [1]unpublished NPS data (Jalbert 1997).

Site 12: Dripping Spring

Description: small hanging garden under cliff overhang with a shallow catchment pool below.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jul 17, 1997; Jan 27, 1998

Site Aspect: southeast
Solar Exposure: unknown
Annual BTUs/sq ft: unknown

Water Discharge (m^3/s): low
Historic Max Discharge: unknown
Water Temp (• C): 17.5
Conductivity (µS): 260
Water pH: 8.1

Natural Disturbance Potential: low
Natural Impact Evidence: none
Other Disturbances: none

Location: Grand Canyon, backcountry
Coconino County, Arizona
Trail: South Hermit Trail
Elevation: 1585 m
UTM: N3991450, E388150
7.5min Topo Quad: Grand Canyon

Accessibility: moderate--hike

Geologic Strata: Coconino Sandstone
Predominant Substrate: sand/loam
Litter/Duff: low density

Soil Temp (• C): 22.0 median (min/max 22.0-26.5)
Soil Moisture (% sat): 68 med (min/max 55-100)
Soil pH: 7.0 median (min/max 6.8-7.1)
Soil Depth (cm): 2.5 median (min/max 0.5-4)
Slope (degrees): 5 median (min/max 2-17)

Estimated Recreational Use: moderate
Recreation Impact Evidence: minor trampled veg, minor litter, worn trail, and water catchment basin
NPS Recreation Estimate: unknown

Primary Vegetation & Estimated Area: *Mimulus cardinalis* (5-10 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Celtis reticulata,* various grass spp.

Mollusks: zonitids--(undescribed sp.)

Other Invertebrates: coleopterans--Elateridae; dipterans--Asilidae, Tachinidae; hemipterans--Gerridae *Gerris remigis*; hymenopterans--Apidae, Pompilidae *Pepsis chrysothermis,* Sphecidae *Bembix* sp., *Sceliphron caemon tarium,* Vespidae *Polistes* sp.; lepidopterans--Papilionidae *Papilio* sp.; odonatids--Coenagrionidae

Site Status: One type of primary vegetation, and diverse invertebrate community. Area secure from high natural and recreational impacts.

KAS Establishment Recommendation: More desirable habitat.

Site 13: Nankoweap "Canyon Grape Spring"

Description: large streamside seep with dense veg and thicket of canyon grape on the upper slope.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Apr 12, 1997; May 13, 1998

Site Aspect: northeast
Solar Exposure: mid AM to late PM (Jan-Dec)
Annual BTUs/sq ft: 407,624

Water Discharge (m^3/s): moderate
Historic Max Discharge: 84.9 m^3/s (creek)[1, 2]
Water Temp (• C): 14.5
Conductivity (µS): 780
Water pH: unknown

Natural Disturbance Potential: low
Natural Impact Evidence: minor flash flood debris
Other Disturbances: none

Location: Grand Canyon, river corridor
Coconino County, Arizona
River Mile: 52.1 RR (83.8 km)
Elevation: 945 m
UTM: N4017075, E421500
7.5min Topo Quad: Point Imperial

Accessibility: easy--boat and hike

Geologic Strata: Muav Limestone
Predominant Substrate: soil/loam
Litter/Duff: high density

Soil Temp (• C): 13.0 median (min/max 11.8-14.5)
Soil Moisture (% sat): 100 med (min/max 80-100)
Soil pH: 6.5 median (min/max 6.2-7.4)
Soil Depth (cm): 15 median (min/max 10-15)
Slope (degrees): 16 median (min/max 10-72)

Estimated Recreational Use: none
Recreation Impact Evidence: none
NPS Recreation Estimate: maybe 10% of all trips, or about 25 visitors/week (extrapolated)[3]--stream channel only

Primary Vegetation & Estimated Area: *Typha* spp. (• 10 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Carex* spp., *Cladium californicum, Equisetum* spp., *Phragmites australis, Salix exigua, Scirpus* spp., *Vitis arizonica*

Mollusks: succineids--*Catinella* spp.; physids--*Physa* (=*Physella*) spp.; limacids--*Deroceras* sp.

Other Invertebrates: arachnids--Tetragnathidae *Tetragnatha* sp.; odonatids--Coenagrionidae

Site Status: Possible flash flood impact and low amount of primary vegetation available. Dense sawgrass and canyon grape restrict hiker intrusion into seep.

KAS Establishment Recommendation: Acceptable habitat.

References: [1]Cooley et al. 1977; [2]Spamer and Bogan 1993; [3]unpublished NPS data (Jalbert 1997).

Site 14: Kanab Creek Seep

Description: large, travertine seep, 2.4 km upstream of the confluence. Dense veg at base.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Nov 22, 1996; Apr 18, 1997

Site Aspect: northeast
Solar Exposure: mid AM to mid-day (Feb-Oct)
Annual BTUs/sq ft: 192,266

Water Discharge (m^3/s): low
Historic Max Discharge: unknown
Water Temp (• C): 19.5
Conductivity (µS): 910
Water pH: unknown

Natural Disturbance Potential: moderate
Natural Impact Evidence: flash flood debris
Other Disturbances: none

Location: Grand Canyon, river corridor
Mohave County, Arizona
River Mile: 143.4 RR (230.7 km)
Elevation: 610 m
UTM: N4030700, E354400
7.5min Topo Quad: Fishtail Mesa

Accessibility: easy--boat and hike

Geologic Strata: Muav Limestone
Predominant Substrate: sand
Litter/Duff: medium density

Soil Temp (• C): 18.9 median (min/max 18.0-21.9)
Soil Moisture (% sat): 100 med (min/max 90-100)
Soil pH: 5.9 median (min/max 5.6-6.3)
Soil Depth (cm): 15 median (min/max 9-15)
Slope (degrees): 27 median (min/max 20-40)

Estimated Recreational Use: none
Recreation Impact Evidence: none
NPS Recreation Estimate: <10% of all trips, or about 25 visitors/week (extrapolated)[1]--unlikely to use seep

Primary Vegetation & Estimated Area: *Typha* spp. (>30 m^2) and *Mimulus cardinalis* (• 15 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Aquilegia chrysantha, Baccharis* spp., *Carex* spp., *Equisetum* spp., *Salix exigua, Vitis arizonica*, moss spp.

Mollusks: limacids--*Deroceras* sp.; physids--*Physa* (=*Physella*) spp. (found in Kanab Creek)

Other Invertebrates: dipterans--Chironomidae; odonatids--Coenagrionidae, Libellulidae *Libellula saturata*

Site Status: Most primary vegetation at seep base--threatened by flash floods in Kanab Creek. No recreation impacts observed or expected; most hikers pass seep on the way to "Whispering Falls" or river confluence.

KAS Establishment Recommendation: Acceptable habitat.

References: [1]unpublished NPS data (Jalbert 1997).

Site 15: Nankoweap "Twin Springs"

Description: large, creekside springs with dense vegetation, about 6.4 km upstream of confluence.

Jurisdiction: NPS-Grand Canyon National Park

Surveyed: Jun 19, 1996; May 19, 1998

Site Aspect: east
Solar Exposure: mid AM to late PM (Jan-Dec)
Annual BTUs/sq ft: 588,295

Water Discharge (m^3/s): moderate
Historic Max Discharge: 84.9 m^3/s (stream flood)[1]
Water Temp (• C): 20.5
Conductivity (µS): unknown
Water pH: unknown

Natural Disturbance Potential: moderate
Natural Impact Evidence: flash flood debris
Other Disturbances: none

Location: Grand Canyon, backcountry
Coconino County, Arizona
Drainage: Nankoweap Creek
Elevation: 1060 m
UTM: N4015350, E420150
7.5min Topo Quad: Point Imperial

Accessibility: moderate--boat and hike, or helo

Geologic Strata: Dox Sandstone/Cardenas Lava
Predominant Substrate: sand/loam
Litter/Duff: low density

Soil Temp (• C): 21.5 median (min/max 20.5-23.6)
Soil Moisture (% sat): 100 med (min/max 80-100)
Soil pH: 6.7 median (min/max 5.8-7.2)
Soil Depth (cm): 15 median (0 range)
Slope (degrees): 10 median (min/max 2-90)

Estimated Recreational Use: low
Recreation Impact Evidence: some campsites and firepits nearby
NPS Recreation Estimate: 2,125 usernights/year and limit of 23 campers/night for whole area[2]

Primary Vegetation & Estimated Area: *Typha* spp. (>10 m^2)

Associated Vegetation: *Adiantum capillus-veneris, Baccharis* spp., *Cladium californicum, Equisetum* spp., *Phragmites australis, Populus fremontii, Salix exigua, Tamarix ramosissima*

Mollusks: physids--*Physa* (=*Physella*) spp.

Other Invertebrates: arachnids--(undescribed sp.); dipterans--Muscidae; homopterans--Cicadidae *Diceroprocta apache*

Site Status: Moderate vulnerability to flash flood impact, and recreational use limited; dense sawgrass keeps most hikers out of seep.

KAS Establishment Recommendation: Acceptable habitat.

References: [1]Cooley et al. 1977; [2]unpublished NPS data (Jalbert 1997).